United States
Department of
Agriculture

Forest
Service

Forest Health Through Silviculture and Integrated Pest Management:

Supporting Appendixes

FOREST HEALTH APPENDIXES

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THROUGH

SILVICULTURE

AND

INTEGRATED PEST MANAGEMENT

Supporting

Appendixes

UNTIED STATES DEPARTMENT OF AGRICULTURE

FOREST SERVICE

Washington, D.C.

March 1988

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PREFACE

The primary sources of information about insects, diseases and atmospheric deposition in the forests of the United States used in the report "Forest Health Through Silviculture and Integrated Pest Management -- A Strategic Plan" were a series of background documents. These background documents were prepared by subject matter specialists working at Forest Service facilities throughout the United States.

These background reports presented are draft papers as prepared by the several authors using a common outline.

The documents are divided into three categories:

1. Nine reports, each on a major forest pest or group of forest pests.

2. Three reports, one each for the North, South, and West regions of the United States are presented. Each report covers the significant forest pests in that geographic region, except for those discussed as on of the nine major pests.

3. Three reports cover the available information on atmospheric deposition in the North, South, and West.

PREFACE

The primary sources of information about insects, diseases and atmospheric deposition on the forests of the United States used in the report "Forest Health Through Silviculture and Integrated Pest Management -- A Strategic Plan" were a series of background documents. These background documents were prepared by subject matter specialists working at Forest Service locations throughout the United States.

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The documents are divided into three categories:

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2. Pest reports, one each for the North, South, and West regions of the United States are presented. Each report covers the significant forest pests in that geographic region, except for those discussed in one of the nine major pests.

3. Other reports cover the available information on atmospheric deposition in the North, South, and West.

SUMMARY OF RESPONSES TO PERCEIVED ISSUES

The pest background documents address nine "perceived" issues that represented current opinions and conventional wisdom about factors affecting forest health. The background documents provide insight into the validity and/or relative importance of these issues. Since forest health concerns are based on both perception and fact, these responses provide insight into how the forest pest managers view the forest health subject and the opportunities for achieving improvements.

The data does not provide evidence establishing that a nationwide deterioration in the health of the forests was taking place. Although increased forest pest activity can be an appropriate indicator of forest health problems, the presence of forest pest populations within the forest ecosystem do not automatically yndicate forest health deterioration. With few exceptions, the frequency and intensity of forest pest outbreaks reflect normal biological system dynamics. The factors triggering recent pest outbreaks, weather favorable to pest survival coupled with an availability of susceptible host trees, are the most common causes. The susceptibility of the host may reflect natural and/or cultural events.

Answers to the perceived issue questions were summarized from the pest background documents.

1. What triggers a decision to take action against a forest pest?

This question was motivated by the perception that forest pest management activities react to rather than anticipate problems. In a majority of the cases, the decision to take action against a pest population is triggered by the prospect of "unacceptable damage" to the timber resource. This was more frequently the case with insect than with disease problems. Political support for action is also a reason to act. Limited funding is identified as a principal reason for the minor emphasis on pest prevention activities in the past.

2. To what extent is aging of the nation's forests related to the incidence of forest pest outbreaks?

The age of a tree is a factor in its susceptibility to pest attack and in its capacity for surviving an attack. The premise implied in the question is that the average age of the nation's forests is increasing and therefore the susceptibility to pest outbreaks is also increasing. Data for forest age trends are not available and it is impossible to make a generalized statement applicable to the whole country. However, stand age is usually one of the factors incorporated into stand hazard rating systems for determining susceptibility to pest attack. Tree age contributes to the relative susceptibility of stands to pest outbreaks.

3. To what extent do forest plans and the National Forest System planning process address forest pests and forest health?

Management plans for National Forest System lands address pest prevention and pest impacts on forest productivity in very general terms. This lack of emphasis on pest management can be attributed to a need for better information, for greater concern about potential pest impacts, and/or for cost-efficient strategies to prevent pest impacts. While the current plans provide discretionary latitude to the manager, they also give the impression that forest pest management concerns are not receiving sufficient attention in the planning process.

4. How does the public's knowledge of forest ecology and forest management influence decisions affecting forest health?

It was hypothesized that the public's lack of knowledge about forest ecology and forest management was responsible for opposition to vegetation management activities important to maintaining healthy forests. Most often identified is the public's simplified idea of how forests should look as the reason challenges occurred to pest-related vegetation management activities. Failure to adequately involve the public in the early phases of planning and decision-making eliminated opportunities to gain understanding and perhaps public support for the need to take management action. When the public recognized the potential for pest damage and impacts, understood the relationship between the proposed vegetation management and pest prevention, and trusted the forest manager, public support for activities to mitigate forest health problems was forthcoming. However, when any one of the above conditions was not satisfied, public opposition occurred.

5. To what extent does the technology exist for enhancing and maintaining forest health?

This question sought to determine whether forest pests can be managed with sufficient success to reduce pest-caused damage. A significant need is for technology that can be incorporated into integrated pest management systems necessary to accomplish long-range prevention objective. To be acceptable to forest managers, control activities must be economically efficient and technologically practical.

In most cases, outbreaks of the pests discussed were closely related to naturally or artificially caused stresses in the forest. Some silvicultural practices to minimize these stresses are available and can prevent or reduce the impacts of bark beetles, dwarf mistletoes, budworms, and root diseases. Pest managers are also confident that the solution to Douglas-fir tussock moth outbreaks is an early warning detection system coupled with treatment of low-level populations. The gypsy moth, as an introduced pest, represents special problems but, once established in an area, can be successfully treated with aerial application of insecticides to avoid unacceptable impacts on high value forest resources. Integrated pest management strategies for all of the pests mentioned are being developed. The one area where the future is uncertain relates to atmospheric deposition/air pollution effects. Remedial strategies will be developed as ongoing surveys provide better information on where air pollution impacts are occurring and about the causes.

6. How have man-caused changes that influence fire activity, ecosystem diversity, and nutrient cycling in the forest ecosystem affected the incidence of pest outbreaks?

This question explores the perception that the forests had a lower frequency of pest outbreaks before man disrupted the natural balances within the forest ecosystem. The objective was to identify counter-productive activities among those activities considered essential by resource managers to achieve specific management objectives. A management strategy that approximates natural processes is generally the more cost efficient over the long term. Unfortunately, many forest management decisions have short-term benefits as their objective. Some examples of how forest management has created forest health problems include activities that maintain stands beyond the entomological or pathological rotation age for the site; artificially regenerated stands with off-site species; failure to perform essential timber stand improvements; regenerated ares with the same species as previously harvested from the disease-infested site; and retaining genetically and otherwise inferior trees of minimal commercial or aesthetic value. The problem is not that man's activities are destructive or unnatural but that the decision-making is too short-sighted and not sufficiently sensitive to the long-term potential for pest damage.

7. How has the increased public involvement in the forest management decision-making process affected forest health?

This question tried to determine how resouce managers viewed the effect of public involvement required by law on vegetation management decisions and forest condition. Public involvement in forest management decision-making has had both positive and negative effects. The extent to which public involvement is successful depends on the objectivity of both the resource managers and the public. There are no universally applicable conclusions. The better informed the public, the more responsive the resource managers, and the more willing both sides are to compromise, the better the prospects for agreeable decision-making. Public opposition to vegetation management proposals does not automatically mean that forest health is at risk. A variety of viewpoints and opinions guarantees that all decisions will be scrutinized by the public. Successful resolution of differences requires that all parties share a common goal and are operating within the same time frame.

8. How have public perceptions about pest-caused damages, losses, value of losses, cost of treatment or prevention, and risks of treatment affected forest health?

This question sought to determine whether public concerns, particularly about environmental quality, were contributing to a deterioration of forest health. In spite of the impressions held by many Forest Service specialists, very few pest intervention activities were successfully or permanently halted by active public opposition. However, the Forest Service may have avoided activities where public opposition was anticipated. In some instances by the time intervention to treat pests was proposed, the forest's health was already questionable, the intervention was a reaction to minimize the impact of the problem. Public opposition, when it occurred, was motivated by concerns other than the timber values at risk or the prospect of trees being killed. An example would be a decision against applying pesticides in order to avoid a controversy. In cases where treatment was restricted or foregone, the reasons were biological or economic, not public concerns about environmental risks.

Political interests are often more responsible for causing treatment to take place than for preventing it.

9. How has forest land ownership class affected forest health; do frequency and intensity of outbreaks vary by ownership; and what factors explain differences?

On the national level, landownership does not appear to be an issue important to the forest health discussion; no class of landownership is uniquely vulnerable to forest pest impacts. However, some local and regional situations exist which are expected to affect the potential threat from forest pests. For the insects and diseases discussed in this report, only the southern pine beetle, dwarf mistletoes, and Douglas-fir tussock moth impacts were related to landownership. The lack of silvicultural activities was identified as the cause for disproportionate southern pine beetle and dwarf mistletoe impacts on non-industrial private lands. National Forest System lands in the South are also expected to have more southern pine beetle damage because of the higher stand densities and longer rotations. The predominance of private ownership in the moisture-stressed transition zone between lowland pine and upland fir stands was cited to explain why private landowners are expected to sustain the greatest damage from Douglas-fir tussock moth responding to the stressed trees.

GYPSY MOTH

Allan T. Bullard

Major Pest : Gypsy Moth (Lymantria dispar [L.])

Background

Distribution

The gypsy moth is a native pest to Europe and Asia that was introduced into the United States in the Boston area in 1869. It is now firmly established in all or parts of the 13 northeastern states from western Pennsylvania, eastern West Virginia and northern Virginia to central Maine. In Canada it is established in southern Nova Scotia, Quebec and Ontario. Outside of this so-called "generally infested area" is an established population in the central Southern Penninsula of Michigan.

The gypsy moth is a regulated pest in the United States and the Animal and Plant Health Inspection Service (APHIS) maintains an active detection/inspection and quarantine program designed to intercept movement from the infested area to other parts of the country and prevent establishment in these areas. Under the nationwide 1986 detection program, moths were collected in all states except Arizona, Mississippi, Nebraska, New Mexico, North Dakota, Oklahoma, South Dakota and Utah and actual isolated infestations were delimited in California, Colorado, Illinois, Indiana, Kentucky, North Carolina, Ohio, Oregon and Washington.

Description of preferred host(s)

The gypsy moth has one of the widest host ranges of any insect pest, feeding on over 300 species of plants. Preferred hosts (those favored by all larval stages and necessary for survival of young instars) are the oaks, especially the white and chestnut oaks, but also include: alder, apple, aspen, basswood, various birches, boxelder, red gum, hawthorne, larch, mountain ash, blue spruce, sumac, willows and witch hazel. Species favored by older larvae also include beech, chestnut, hemlock and all species of pines and spruce.

Area occupied by host vegetation (acres by ownership)

Preferred host species (those favored by all larval stages and capable of sustaining gypsy moth populations) occur naturally throughout all parts of all states east of the Great Plains with the exception of extreme southern Florida. Preferred hosts also occur naturally but sporadically in all states west of the Great Plains. "Pockets" of preferred host occur off-range in urban and suburban areas in the west, where they have been planted as ornamentals by residents translocating from the east. These pockets complicate the host situation by artificially creating areas where gypsy moth populations can develop then spread

to surrounding forestlands containing species that are not primary host but are capable of supporting gypsy moth populations.

Due to the extremely large number of actual and potential hosts of the gypsy moth, it is virtually impossible to determine the acreage occupied by these hosts nationwide. The figures below were compiled from Forest Resource Report #23, "An Analysis of the Timber Situation in the United States 1952-2030". Only six forest types were included in compiling these figures: Oak-Hickory, Oak-Pine, Oak-Gum-Cypress, Maple-Beech-Birch, Aspen-Birch, and Western Hardwood. These six types represent the majority of the preferred host types of the gypsy moth. The Maple-Beech-Birch type does not technically include much preferred host, but a great deal of oak is present in this type so it was included. Because not all preferred hosts are represented by these types, the figures are conservative estimates of the potential range of the pest.

Total acres of forest land (US) = 736.6MM

Total acres of the 6 types = 240.5MM (32.7% of total forested area)

Acres of host by ownership (MM acres)

National Forest	Other Public	Forest Industry	Farm/ Private	Total
17.18	20.90	28.92	173.57	240.57

Outbreak cycles and triggers

Throughout its natural range (Europe and Asia), gypsy moth outbreaks are a reasonably cyclic phenomenon, occurring at about 7-9 year intervals. Outbreaks appear to be weather-related, with drought conditions normally indicating a pending outbreak within 2-4 years. In the United States, because the insect was introduced and has not yet occuppied the entire area that is susceptible to it, a different situation exists.

In areas such as Massachusetts where the pest has been established for over 100 years, outbreaks are periodic, although a definite cycle has not been established. Since 1924, there have been 7 well-defined outbreaks ocurring at intervals of as little as 2 years to as many as 14 years. These outbreaks have lasted for 2 to 4 years each. In states such as Maryland where the pest is just becoming established, the outbreak phase began in 1980 and has continued through the present. In the Maryland case, it cannot be stated that the "outbreak" is occurring over the entire state. The northern and eastern parts of the state were infested and showed defoliation in the early 1980's, but while the total acreage defoliated in the state by year has increased each year since then, the areas first infested no longer have defoliating populations present. The defoliation reported by the state is occurring primarily in areas that are currently being infested and have not been defoliated previously.

The most recent large-scale outbreak in the US began in 1980 and lasted through 1983. During this period, over 28,000,000 acres were defoliated. This was the largest outbreak ever recorded in the US and in 1981 alone, nearly 13,000,000 acres were defoliated.

Research has been conducted to determine the triggering factors of outbreaks in the US, but the results are inconclusive. There are indications that weather plays an important role, particularly drought and winter temperatures and snowfall, but a definitive relationship has not yet been established. Another factor contributing to outbreaks appears to be the quality of the host species in the area. Changes in foliage quality following defoliation lead to less vigorous pest populations, insect size becomes smaller and fecundity and fertility are reduced. These factors seem to relate to outbreak collapse, as do crowding (apparently facilitating the transmission of the gypsy moth virus), starvation, and the build-up of predator populations. Subject specialists theorize that the reverse of this condition could lead to the onset of outbreaks and work has begun to investigate this possiblity.

Attack behavior/damages

Unique characteristics of the gypsy moth that influence its spread and have been responsible for the slow infiltration of the host range include its method(s) of dispersal and the fact that the female moths do not fly. Primary dispersal is through wind transport of first instar larvae in the spring. Since the pest was introduced in the northeastern part of the country and the prevalent winds are from the west-southwest, movement from New England has been extremely slow. The second factor slowing natural spread is the lack of flight of the adult female moth. Upon emergence as adults, females seldom move more than 1-2 feet from their pupal cases. They attract the strong flying males with a pheromone, are mated and lay their eggs in sheltered areas near where they pupated. Some natural spread is through migration of older larvae in search of food, although this migration is limited to less than several hundred feet and does not appear to play much role in the movement of the pest into uninfested areas.

Primary damage caused is defoliation which is is often dramatic during outbreak phases, with whole ridges being completely stripped of leaves in late June-early July. In the case of hardwoods, seldom does even severe defoliation cause mortality of the hosts directly, although growth loss occurs. In areas receiving their first defoliation, if no other stress factors (eg. drought) have affected the stands, most trees will refoliate later in the summer. In areas receiving their second or third consecutive year of severe defoliation however, many of the trees are not capable of refoliating and succumb. Recent evidence shows that even with one defoliation oak mortality may be as high as 20 percent. In drought stricken areas it may be as high as 50-70 percent.

Secondary damage is through mortality. In most cases, mortality results from invasion of defoliation-weakened tress by secondary organisms such as the two-lined chestnut borer and the shoestring fungus. Hardwood mortality has averaged about 15% following gypsy moth defoliation, but has ranged from about 5% to 100%. In the case of conifers, such as hemlock, a single complete defoliation will kill the tree because of inability to refoliate.

Current situation (as of 6/30/87):

Status of outbreak(s)

1) Generally Infested Area

When dealing with the gypsy moth, an "outbreak" can be defined as occurring when defoliation is widespread throughout the entire infested area rather than basing an outbreak on the total acres defoliated in any given year. This is true because while large areas are defoliated every year, in most years, the majority of the defoliation occurs along the advancing front of the infestation. Since the pest is moving both west and south into previously uninfested areas, the total area at risk of defoliation is increasing rapidly each year. The last actual outbreak of the gypsy moth occurred between 1980 and 1983, as mentioned above. In 1984, reported defoliation nationwide was less than 1 million acres. In 1985 and 1986, nationwide defoliation increased to 1.9 and 2.4 million acres respectively, with significant but sporadic defoliation reported throughout most of the generally infested area. It is not known at this time if this indicates that a new outbreak is beginning. Defoliation in 1987 appears to be about the same or slightly less than reported in 1986, withh most occurring along the advancing front.

2) Isolated Infestations

Isolated infestations are areas outside of the contiguously infested area where gypsy moth has apparently been artifically introduced and is becoming established. These areas, by definition, are in outbreak status. Since efforts are made to locate, delimit and eliminate these infestations, the number of active sites throughout the country varies each year. According to data provided by APHIS, 66 such sites have been located and treated in various locations around the country since 1982. The sites have totalled over 500,000 acres but have varied in size from about 10 acres to over 200,000. In 1987 two sites, one in North Carolina and one in Oregon, were treated to attempt eradication of the pest. Results of these eradication attempts are not known at this time.

Percent of host habitat occupied.

Exclusive of isolated infestations, the gypsy moth is present and has the potential for causing defoliation in approximately 48,000,000 acres of the United States. This represents about 20% of the area of host type in the nation. The pest is advancing both west and south from the generally infested area at a rate of about 5-10 miles per year, thus occupying its host types at a rate of about 1% per year. Due to the expanding "front" caused by the shape of the nation (relatively narrow between the Atlantic Ocean and Canada in the area currently infested but widening rapidly to the south and west of this area), the rate of percent host infested will increase rapidly in the future even with no increase in the rate of movement by the pest.

Acres occupied

As mentioned above, approximately 48,000,000 acres of host type is currently occupied by the gypsy moth. This includes essentially all host type in the New England States, all of New York, Pennsylvania, New Jersey, Delaware and Maryland, about 5% of West Virginia, 15% of Virginia, and about 5% of Michigan. At the current rate of spread, it is possible that by the year 2000, most of Virginia, West Virginia and much of Ohio will be infested, with the infestation extending also into extreme eastern Kentucky and Tennessee and northern North Carolina.

Course of the outbreak

When did outbreak start?

Major outbreaks of the gypsy moth (since 1924) began in 1926, 1932, 1944, 1952, 1962, 1969 and 1980. These outbreaks ended in 1929, 1941, 1946, 1954, 1965, 1974 and 1983 respectively.

Where did each start

The outbreaks all were indicated by a general increase in total defoliation throughout the area infested at the time of the outbreak and cannot be traced to a single point source (focus) from which the remainder of the outbreak developed.* The 1944-46 outbreak is illustrated below as an example:

Acres of Defoliation by State (1943-1947)

	State						
Year	CT	MA	ME	NH	RI	VT	Total
1943	0	34,481	10	290	64	0	34,845
1944	14	225,637	21,221	2,346	640	210	250,068
1945	16	456,832	210,881	58,517	1,280	93,950	821,476
1946	486	217,132	203,813	183,943	1,645	15,900	622,919
1947	0	7,256	0	166	0	0	7,422

* A current theory holds however, that outbreaks do begin from multiple foci (locations that favor the sustenance of low level gypsy moth populations at all times) and when conditions are proper, these populations explode into surrounding areas, thus initiating the outbreak.

Expectations for future outbreaks

Future outbreaks will occur and will continue to break all previous defoliation records, as did the outbreak of 1980-1983, simply due to the increase in the total area at risk. As can be seen from the historic pattern, outbreaks have not occurred at any regular interval in the US. Research has been and is being conducted to attempt to develop a reliable outbreak predictor. There are some promising leads, but these are based on short term phenomena and prediction of outbreaks long into the future is not possible at this time.

It is anticipated that total annual defoliation acreage will remain in the 2 to 5 million acre range for the next one to three years. By that time, the majority of the infested area will have been without outbreak for about 7 years and the likelihood of widespread defoliation will increase. It is a safe assumption that the next major outbreak will occur between now and 1995. There is no evidence to indicate that outbreaks are occurring more frequently now or are more damaging now than in the past.

Causes of this outbreak

There is no present gypsy moth outbreak, meaning that high pest populations and significant defoliation are not being reported from throughout the generally infested area. Scattered areas behind the advancing front are experiencing these situations, but these are isolated occurrences. The vast majority of the defoliation being reported each year is occuring in the advancing front, where new areas are being infested for the first time. These types of areas will always be defoliated, and if the sole measure of outbreak vs. non-outbreak status is total acres defoliated, the actual outbreak situation in the country will be obscured.

Since no outbreak is occurring, it is best to examine the latest outbreak that did occur, the 1980-1983 outbreak.

As stated previously, there are no defined factors in the US that can be used to predict outbreaks. Weather has a major role in outbreak initiation, and many of the actual parameters that are important are known. It is known, for instance, that dry spring weather leads to increased survival rates of gypsy moth eggs and young larvae which in turn leads to higher population levels and increased scope and intensity of defoliation during that year. It is also known that extremely cold winter weather, particularly in the absence of snow cover, leads to increased egg mortalitiy. This appears particularly true if the cold weather is preceded by abnormally warm temperatures in mid winter that initiate embryo development. Freezing temperatures in the spring following egg hatch and/or very heavy rains before young larvae become established on leaves cause high larval mortality due to freezing or drowning. All of these factors influence larval survival and ultimately the size, health and vigor of subsequent populations. The order in which these various parameters influence population size is elusive. It is probable that all have essentially the same relative importance, and if weather patterns develop that are conducive to survival, an outbreak will be initiated. There is some evidence that 1979-80 provided meteorologic conditions conducive to the survival and buildup of gypsy moth throughout the generally infested area (dry spring, moderate winters, etc). More normal weather patterns existed in 1981-1982, but by then there were extremely high populations present over most of the infested area and the outbreak was well established.

Examination of management practices, cultural, economic and other factors over time indicates that there were no significant changes in any of these factors prior to the outbreak, so that none of these would have been a probable contributing cause of this outbreak.

Since there appear to be no deviations to historic gypsy moth/host management that might have contributed to the most recent outbreak, it is impossible to develop a with/without deviation description.

Current control program(s).

There are two types of control programs in effect for gypsy moth. Eradication projects take place under the auspices of APHIS outside of the generally infested area and are designed to eliminate the target infestation. Suppression activities take place under the Forest Service either cooperatively with the states or directly on Federal lands inside of the generally infested area and

are designed (for the most part) to protect high value forest resources. Eradication projects are based on the simple presence of multiple life forms of the insect and the need to eliminate the infestation entirely. Suppression projects are conducted on the basis of threat to high valued resources. Value, here, being defined by the land manager and including aesthetics, nuisance abatement, recreation, water quality, wildlife or other factors in addition to timber values. Most state projects therefore manage for the effects of the insect rather than for postponing or preventing the initiation of gypsy moth outbreaks.

Eradication projects employ various tactics to eliminate the target infestations. Tactics include the use of extensive male moth trapping, overflooding with sterile male moths, release of partially sterilized eggs, and multiple applications of biological and/or chemical insecticides. Suppression projects are directed against potentially damaging pest populations and usually only employ aerial applications of biological or chemical insecticides as the other tactics mentioned have not been shown to be operationally successful against high population densities.

Acres treated by type of treatment

This section will deal with suppression activities that have taken place within the generally infested area and will cover the 1980-1983 outbreak and the activities that have taken place from 1983 to June 30, 1987. Eradication projects will not be addressed as they are outside the purview of the Forest Service.

The table below displays the number of acres treated by insecticide under joint State/Forest Service cooperative suppression programs from 1980 through the present. These projects all involved the aerial application of the various insecticides.

Acres of Treatment by Insecticide

Year	Carbaryl	B.t.	Dimilin	Other*	Total
1980	18,517	16,963	0	44,814	80,294
1981	117,085	22,437	0	210,598	350,120
1982	160,242	67,324	77,918	421,246	726,730
1983	71,468	475,898	46,500	4,894	598,760
1984	37,040	218,324	252,769	4,072	512,205
1985	2,192	268,975	247,322	0	518,489
1986	8,755	219,323	350,992	0	579,070
1987	3,704	306,825	375,872	0	686,401

*This category includes primarily Dylox and Orthene.

Other insecticidal treatments were made by the states alone and other activities were also undertaken, primarily the innoculative release of gypsy moth parasites. These other efforts were largely unsuccessful, although some parasites have been established as a result of these programs. Beginning in 1982, a joint state/Forest Service pilot project was established and has been conducted in Maryland to evaluate management tactics directed at low level gypsy moth populations. The study is in its final year and will compare the degree of

resource protection acheived through the normal suppression approach versus the approach used in this integrated pest management project. The project has provided some leads in the management of low level populations, namely the application of luretape as a male confusant, the use of Gypcheck and the application of B.t. at very low egg mass densities. The greatest contribution of the project has been in establishing the design necessary for a grid monitoring system to track gypsy moth infestations on a systematic basis over large areas.

Percent of total infested acres treated

The following table shows the acres defoliated and treated by year since 1980 and the percent of the total affected area that was treated. Since acres treated in a given year is primarily a function of the acres defoliated in the previous year, the percentage calculation was made on the basis of acres treated/acres defoliated in previous year. This table only represents the suppression activities under the cooperative state/Forest Service suppression programs in the generally infested area.

Percent of Total Area Treated by Year

Year	Acres Defoliated	Acres Treated	% of Defoliated area treated
1980	5,005,000	80,294	12.5
1981	12,873,000	350,120	7.0
1982	8,171,000	726,730	5.6
1983	2,383,000	598,760	7.3
1984	993,000	512,205	21.5
1985	1,900,000	518,489	55.6
1986	2,413,000	579,570	30.5
1987	not yet known	686,401	28.4

Costs

There are obviously many costs associated with the gypsy moth and gypsy moth suppression. Few of these are quantifiable. Total expenditures for the cooperative suppression projects are known, but it is not known, for instance, how many acres were treated and at what cost by homeowners on their own land. Also not known is the amount spent to protect private campgrounds and other private recreational areas. The table below presents only the costs of the cooperative state/Forest Service suppression projects from 1980 through the present. These projects, as described previously, have involved only the use of aerially applied chemical and biological insecticides. From the above discussion then, it is apparent that this is a conservative estimate of the total spent on gypsy moth control.

Suppression Expenditures by Year and Acres Treated (cooperative state/Forest Service projects only)

Year	Acres Treated	Total Cost	Cost Per Acre
1980	80,294	$1,421,395	$17.70
1981	350,120	4,645,837	13.27
1982	726,730	9,716,711	13.37
1983	598,760	7,977,537	13.32
1984	512,205	6,183,577	12.07
1985	518,489	5,621,066	10.84
1986	579,570	6,895,344	11.90
1987	686,401	8,713,144	12.69
TOTALS	4,052,569	$51,174,611	$12.63

Impacts

Number of Acres Affected

Since 1980, defoliation has occurred on approximately 33 million acres in the northeast and Michigan. Impacts within this affected area have varied depending upon forest type and land use.

Physical Loss

Physical losses due to gypsy moth outbreak occur from defoliation and its effect upon tree growth, tree mortality, aesthetics, recreation, and mast production. Of all of the effects of defoliation, the effect upon tree growth and mortality has been studied the most. Defoliation stresses trees and results in a direct reduction in tree growth of 40 - 60% (both diameter and volume). Trees that are stressed are often invaded and killed by opportunistic organisms. Stress from defoliation, as well as other sources such as drought, will result in tree mortality. On the average, 15-35% of the susceptible trees in a stand die as a result of gypsy moth defoliation. Loss can be measured in two different ways, one looking at overall effects on the entire resource at risk and the other looking at the effects only in areas that have been defoliated.

Resource-wide effects

Results from a recent study in south central Pennsylvania measuring 600 plots randomly placed in advance of gypsy moth defoliation indicate that, on average, 22% of the oak trees died and, of these, 41% were Chestnut oak. Tree mortality, however, is apparrently not well distributed. For example, only 4% of the plots used in the above study lost more than half their trees. On two-thirds of the plots mortality was less than 20%. Tree mortality is, however, related to cumulative defoliation. In this study, mortality increased from 12% in areas where defoliation averaged less than 10% over 3 years to over 27% in areas where defoliation averaged over 40% over 3 years. Just as important as knowing how much defoliation and tree mortality occurs is knowing how the total resource

responds. The Pennsylvania study plots revisted after 8 years indicate a reduction in the oak component from 59 sq feet of basal area per acre to 55 sq ft per acre. Oaks are still the major component of these forests, but species less vulnerable to gypsy moth, such as red maple, black gum, yellow poplar, now make up a greater portion of the stands. In south central Pennsylvania, most of the losses in timber volume were offset by growth. Changes in total volume over a 7 year period ranged from -36 to + 15 cords per acre, and sawtimber ranged from -11,000 to +6,000 board feet per acre, with the average being +350 bdft per acre. Changes in value ranged from -$410 to +$450 per acre with the average being +$11 per acre or +8%. The average compound rate of change in timber value was +2%.

Effects in areas that were defoliated

Another study conducted in Pennsylvania generally confirms these results, indicating that overall mortality due to the gypsy moth averaged 14 percent following one year of defoliation, 38 percent after two years and 48 percent following three years of defoliation. This study took place on 57 permanent plots on stands that had been defoliated. Oak mortality was significantly higher with 18 percent after one year, 89 percent after two and 98 percent after three years of defoliation. In addition to this study, a damage survey was conducted on over 7,000 plots between 1972 and 1984. The survey was conducted in areas exhibiting tree mortality following defoliation and indicated 30% overall mortality on 350,000 acres and more than 50% mortality on 341,000 acres following the 1980-83 outbreak. While these figures are biased in favor of areas actually defoliated and containing mortality vice all potential host type, they indicate that when defoliation occurs, impacts can be serious. Losses in the 691,000 acres averaged 1,400 board feet in sawtimber and 300 cubic feet in pulpwood per acre with a combined value of $150 per acre and a total value of over $100 million.

Use Loss

Use loss due to a gypsy moth outbreak is not generally available. However, a 1977 report documenting recreational losses in the northeast lists recreational use loss of private homes ranging from 50-180 days per year, and commercial recreation loss as 161 person-days per year during an outbreak. Losses in both cases result from defoliation and larval nuisance. A study conducted by the Allegheny National Forest in 1986 showed a 20% reduction in visitor use days by campers as a result of the presence of large gypsy moth populations in developed recreation areas. Sightseers are also impacted by the gypsy moth, but these impacts were not evaluated in the study.

Monetary Value

While no actual estimates of the monetary value of losses to the gypsy moth have been made, using the above studies it is possible to construct a conservative estimate of losses (primarily timber losses) that occurred as a result of the 1980-83 outbreak.

Using the Pennsylvania loss figure of $150/acre for the 691,000 acres exhibiting extensive mortality out of the 6,680,394 acres that were defoliated in Pennsylvania between 1980 and 1983, an average loss of $15.51/acre defoliated can be calculated (691,000 acres of mortality/6,680,394 acres defoliated x $150/acre). By multiplying this amount by the total nationwide defoliation acreage during this period (28,432,000 acres), a figure of $441 million is

attained. However, this assumes that markets are available to use all the trees that died and that all timber is accessible. In reality this is seldom the case. As noted, this figure is conservative, as it does not include recreational, aesthetic, homeowner or other losses.

Other (Fire risk, hazard trees)

While there have been no assessments made to quantify the actual losses or risks of this nature that can be ascribed to the gypsy moth, it is assumed that the increase in dead branches and trees resulting from an outbreak will increase the risk of fire , etc.

Control Responses

Controls taken on this outbreak.

As indicated previously, extensive suppression activities took place during the 1980-83 outbreak. Between 1980 and 1983 over 1.7 million acres were aerially sprayed at a cost of nearly $24 million (see table, pg 9).

Controls that could have been taken.

The management response to gypsy moth, before, during and since the outbreak has been to protect high value resources from the effects of the insect and to leave the vast majority of the infested area untreated. The treatment area selection criteria implemented in State programs typically allocates available funding for treatment of forested residential areas, high use recreation areas, and high value forests (uninhabited) in that order. Most if not all programs also require one year of defoliation as a prerequisite to treatment. This response addresses the socio-political realities of gypsy moth but does little to suppress, manage or otherwise influence insect populations on a regional basis.

The theory behind this strategy is that the highest valued areas will be protected during the outbreak while the outbreak itself is allowed to collapse naturally due to overcrowding, starvation, virus, etc. The theory is sound from the standpoint of protection of resources. It is flawed though in that nothing is done to prevent outbreak initiation or hasten collapse and that by ignoring the vast majority of the forested areas, the certainty of future outbreaks is assured and the probability for outbreaks is actually enhanced.

It is unlikely that any control response other than an increase in suppression activities could have been taken. What is more likely is that gypsy moth management policy and treatment area selection criteria might have been modified and resources allocated to manage the insect rather than its effects; however, this response probably would have been no more effective than the one implemented in controlling the outbreak given the tiny proportion of infested acres actually treated from 1981-1983.

Of the states with active gypsy moth programs, all but one manage for the effects of the insect. West Virginia has been pursuing a policy of preventing defoliation from occurring anywhere in the State and retarding the movement of the insect into other areas of the State. The program began in 1983 and successfully prevented defoliation that year and in 1984. The weakness of this control response is that it requires that the annual allocation of resources keep pace with the increase in insect activity if it is to be successful. A

modest amount of defoliation has occurred in West Virginia each year since 1985, and it has reached the point where the State cannot afford to maintain its current gypsy moth management policy. It is likely that West Virginia will modify its program, and like other States begin prioritizing control responses.

What if no controls had been attempted?

During the three years of the outbreak when control responses were initiated (1981-1983), more acres were treated in each of these years than during any time in the past. In spite of such accelerated control responses, no more than 7.3 percent of the defoliated area was ever treated in any one year. Given such modest control efforts in comparison to the extent of the outbreak, it is unlikely that the outbreak would have lasted longer or caused significantly more damage than it did. All of the control responses were directed at reducing damage and insect nuisance in forested residential and recreation areas. Little if any effort was directed towards retarding spread along the leading edge, or controlling insect activities in forested areas. Defoliation during the outbreak years probably would have been about 7 percent greater each year if no controls were attempted. This percentage represents the acreage that was treated each year during the outbreak.

What could have been done to preclude this outbreak?

Excluding West Virginia (which will probably soon succumb) virtually all the states within the generally infested area and along the leading edge have come to terms with the fact that effective and efficient widespread suppression programs are a logistical nightmare (due to the biological time frame in conjunction with the appropriate meteorological conditions required) and a major economical drain on existing budgets. In light of this, most state pest control authorities have had to resort to various methods of prioritizing their suppression activities in hopes of gaining the most return from their dollars spent. Under these circumstances, even though the state budgets and suppression activities reacted in an effort to protect the increased infested areas meeting the qualifying criteria, vast acreages were left untreated leaving gypsy moth populations to build and collapse on their own. It is doubtful that the widespread gypsy moth outbreak of 1980-83 could have been avoided.

What can be done to prevent future outbreaks?

In the past, the major thrust in managing the gypsy moth has been towards suppressing localized heavy populations where defoliation has either occurred the previous year or is imminent and the resource is worth protecting. This strategy has lent itself to accepting the possibility of damage or loss on less valuable unprotected resources and the fact that recurrent outbreaks and the spread of gypsy moth to new areas are inevitable.

An alternative to the reaction strategy however, is management of gypsy moth at low level populations. Recent research in this area suggests that this approach not only may prevent a widespread outbreak, but would also provide an opportunity to utilize a broader range of control tactics. Key elements to such a strategy would involve: 1) implementing a monitoring program to detect building populations and suppressing populations within the generally infested area; 2) continued suppression activities along the "leading edge" and implementing a monitoring program in areas of low populations; and 3) implementing an early detection program in areas outside of the generally infested area. Within each management area silvicultural methods could be

employed to alter the preferred host habitat and thus reducing stand susceptibility and vulnerability that leads itself to a population build-up. However, the costs associated with this approach to the problem would be significantly higher initially and action would have to be taken in areas not likely to be defoliated for several years.

Treatment Options

As mentioned, there are two types of control programs in effect for gypsy moth, eradication and suppression. Eradication programs take place outside the generally infested area and are designed to eliminate infestations. Suppression programs are conducted within the generally infested area and are designed to decrease defoliation/mortality/nuisance. Many more tactics are available for eradication projects than for suppression, simply because the pest population densities are so much lower. A change in overall strategy within the generally infested area would bring all tactics into operational use in all areas.

Techniques

1) Male moth trapping

This technique has been used extensively both in an effort to more precisely delimit an infestation and to "trap out" populations. Usually the pheromone traps are placed in an infested and buffer area at the rate of 24 to 36 traps/sq. mile. On the average, approximately 40 delimitation surveys at 4 sq. miles/survey are conducted. The technique has been used sporadically and only in an eradication mode so it is impossible to determine losses averted, acres benefiting from treatment on other acres, and total acreage of treatment with this technique is not available (but is known to be small). The cost of implementing this technique is probably in the range of $20/trap, primarily representing personnel costs. This technique has only been shown to be effective in areas with less than 50 egg masses per acre.

2) Inherited sterility technique

The inherited sterility technique as applied to gypsy moth has only been tested for use within the last 3 years. This technique involves the ground or aerial release of partially sterile eggs. The eggs hatch synchronously with the wild eggs, the larvae hatching from the partially sterile eggs are sterile and develop at the same rate as the wild larvae. The sterile larvae develop into adults which are sterile. These sterile adults compete with the wild populations for feral mates and result in sterile eggs. This technique has been used in an evaluation mode on approximately 200 acres/year. As above, it is impossible to determine losses averted, acres benefiting or, in this case, even costs, since the technique is still being reserached (the cost of the sterilzed egg masses is about $50 per 1,000). Also as above, this technique has only proven effective in areas with fewer than 50 egg masses per acre.

3) Ground application of insecticides

Ground application of insecticides is not used in suppression programs under either the State or State/Federal programs. It is used frequently in eradication projects and widely used in the generally infested area by homeowners and on recreation sites. The most commonly used insecticides are <u>Bacillus</u> <u>thuringiensis</u> (<u>B.t.</u>) and Sevin 80S. Homeowners generally use one

application per year, while in eradication projects, one to up to six applications are made depending on the duration of egg hatch. Costs of these applications are considerable, with homeowners paying between $10 and $20 per tree with an average cost of $276 per homesite and recreational areas averaging $607 per site. Comparable costs are incurred during eradication programs. It is not possible to estimate losses averted or other acres benefiting from these treatments, as they are only made in small, localized areas. This technique can be used against all population densities.

In eradication projects, ground application of insecticides is generally followed by trapping-out the area with male moth traps or by the release of sterile insects.

4) Aerial application of insecticides

Current Federal/State suppression projects use the biological insecticide *Bacillus thuringiensis* and the chemical insecticide Dimilin, with the chemical insecticide carbaryl being used extensively by private applicators. Since 1980, chemical and biological insecticides have been applied to approximately 550,000 acres/year and are responsible for the reduction of defoliation and larval nuisance as well as population reduction. The cost per acre averaged $12.63 although for *Bt* and *Dimilin*, the costs are $16 and $8 per acre respectively.

Since treatment under these programs is directed at only the highest valued resource, a case could be made for using the loss figures developed by the second Pennsylvania study mentioned above to calculate what losses were averted. Using that study (which showed an average loss of 1,400 board feet and 300 cubic feet per acre over 691,000 acres and a combined value of $150/acre on acres defoliated and showing mortality) it could be concluded that these losses were averted on the 1,756,000 acres that were treated during the 1980-83 outbreak. This equates to a total of $263,400,000 in benefits and favorably compares with a treatment cost of about $24,000,000.

Technology Information

Adequacy of available technology to prevent or reduce the frequency of outbreaks

Past management efforts have been directed at reducing the impacts caused by this insect in selected high value areas and not at preventing outbreaks or reducing their frequency. In 1982 a special project was begun in Maryland with the objective of applying all available knowledge to maintain gypsy moth populations below damaging thresholds. This project will conclude in 1988. In 1983, research was accelerated on addressing this specific question. These projects and studies have produced a number of techniques that, when used against low level populations, may have an impact on the development of outbreaks. Some of these techniques have proven their value while others are in various stages of evaluation. Beginning in 1987, a demonstration project will be begun using these tactics with the intent of slowing the spread of gypsy moth through the Appalachian Mountains. It is thus premature to judge the adequacy of available technology to prevent or reduce the frequency of outbreaks.

Technology needed to prevent, reduce or control future outbreaks

While noted above that there are some techniques available to help prevent future outbreaks, much more is needed to insure this capability. Major current needs include:

- Reliable outbreak predictors
- Improved microbial insecticide formulations
- Biotechnology and genetic engineering
- Silvicultural methodology
- Fine-tuned hazard and risk rating models
- Improved survey methods, especially at low population densities
- Improved aerial application technology (including insecticide efficacy and efficiency)
- Sound F1 sterility technique (including a competitive strain of the insect, improved production methodology, improved application techniques and improved evaluation techniques)
- Evaluation of Luretape
- Development of an aerial application expert system

Additional discussion not presented elsewhere

1) Obstacles to the use of existing technology

The major obstacle to the development and use of additional control techniques (i.e., other than the aerial application of insecticides) is the present policy of only funding or conducting treatment for moderate to dense populations of gypsy moth. We do not attempt to prevent outbreaks but only to suppress populations capable of causing moderate to heavy defoliation, and only on high value lands. In an effort to suppress these populations, only the application of insecticides is effective. We need to concentrate our efforts on low to moderate populations in an effort to prevent population buildup and defoliation; and therefore, have various control techniques (e.g., inherited sterility, Gypchek, Lure-tape) available for use. This statement is true for the USDA Forest Service and for the infested States as well.

Assuming a change in policy, the greatest obstacles to implementation will be the dollars and personnel needed to implement a survey and monitoring system over the entire infested area (and beyond) and to actually apply the appropriate management techniques throughout this area.

2) Limitations imposed by laws or policies

Certain laws and policies (other than those discussed above) do preclude the implementation of some of the appropriate tactics. For instance, the State of Connecticut has a law prohibiting the aerial application of insecticides in certain types of situations, including those where gypsy moth is a widespread pest. The New Jersey Department of Agriculture has a policy of only using B.t. in their State-sponsored suppression program. This is significant because B.t. has been shown to be less effective overall than many of the other insecticides available for use against the gypsy moth. Likewise, the Pennsylvania Department of Environmental Protection allows only the use of B.t. in residential areas, even though other, more effective, insecticides are registered for use in these areas. National Park Service policies also impact the ability to implement gypsy

moth management programs on their lands, although Park Superintendents seem to have the flexibility to interpret national policy at the individual park level. The policy states (paraphrased) that no actions will be taken to control natural forces on NPS lands. Some superintendents interpret this to mean action against native insects and since the gypsy moth is an imported and regulated pest (even though their park might be in the generally infested area), they are free to take whatever action is appropriate to rid their park of the problem. This has resulted in an inconsistent program within the NPS, with some parks taking action and some not. In the Forest Service, Forest Supervisors are reluctant to use any insecticides on the forests, simply because of the anticipated outcry from the public (particularly environmental organizations). When insecticides are used on NFS lands, the total area that should be treated generally is not, and chemical insecticides are not selected for use (even though recommended) because of the anticipated court challenges that would probably result.

The most significant law that prevents, precludes or delays the implementation of sound gypsy moth management actions is the National Enviromental Policy Act (NEPA). States have come to realize that in order to obtain cost sharing of their suppression projects (thus treat significantly more acreage than they could using only their own finances), they must participate with FPM in the development of site specific environmental assessments under NEPA. Forest Supervisors as well understand the NEPA process, but they also realize the personnel and program impacts that the preparation of an environmental assessment for the aerial application of an insecticide will have on their staffs. With this knowledge, there is a tendency to delay implementation of insecticidal application projects to avoid these impacts in the mistaken belief that the problem might go away on its own. When it becomes apparent that action must be taken, even though the use of chemical insecticides might be included as potential alternatives in the EA, these alternatives tend not to be selected in favor of less effective (but more "publicly palatable" materials) to preclude the virtual certainty of more staff impact due to legal challenges to their decision.

3) Perceived issues

a. Aging of forests

Aging could have a direct bearing on mortality. Trees nearing rotation are generally less vigorous than younger trees and are thus more likely to be killed following defoliation. This appears to be borne out by research. There does not appear to be a relationship between tree (or stand) age and outbreak initiation except in the case of very young (less than 20 year old) stands. There is probably no need for additional work in this area relative to the gypsy moth.

b. Forest health in forest plans

In the plans reviewed from NA, very few dealt completely with forest pests and none dealt with forest health. When this was commented on, R-9 indicated that since separate NEPA documentation would be needed in order to address actions against specific pests, they would wait and cover the problem then. Most plans covered all of the tree-growing aspects of forest manangement quite well and since good pest management begins with good forest management, a case could be made in favor of their position.

c. Action triggers

Biological evaluations that indicate either unacceptable residential or recreational impacts or the imminent threat of significant tree mortality (in that order) are the usual triggers for action against the gypsy moth. Because biological evaluations are generally conducted in response to a request for assistance, the implication is that a problem already exists. This type of approach precludes the establishment and implementation of any type of preventative programs. Efforts have begun (on a small scale) with certain States, several National Forests and several National Parks in NA to implement gypsy moth IPM programs. The basis of these programs is systematic monitoring to detect and evaluate low level populations and population trends so that management tactics other than the aerial application of insecticides can be applied. As stated previously, money and availability of people to conduct the surveys and collect the data needed are the major roadblocks to insuring that these projects will succeed.

d. Public knowledge of forest ecology and management

The majority of the "public" has no or very little knowledge of forest ecology or forest management but certain sectors of the public are very knowledgeable. These sectors, generally represented by so-called environmental organizations, are extremely vocal and make sure that their voice (the voice of the "public") is heard whenever decisions about forest or pest management are to be made. They obviously have an impact on the actual decisions that will be made (see comment above on limitations caused by policies and laws). The majority of the public however, seems to feel good about the Forest Service and the way we approach management of the forests. To most, a well managed forest is one that contains nice trees, good streams, some wildlife, etc. It is upsetting to see something they do not understand, such as a large clear-cut, but if the reason for the action is explained, they indicate understanding. The Forest Service and all public agencies that manage forests need to do a better job of informing the public about the state of our forests, the principles of sound forest management and the reasons for actions that are taken.

e. Technology for maintaining forest health

Most of the technology needed to maintain the forests in the face of gypsy moth is available. Aside from developing local hazard and risk rating systems and development of sound low level survey methods, the previous comments about the various needs from research and others generally indicate only the need for enhancement of existing technology. What is needed for gypsy moth is the committment on the part of forest managers and forest pest managers, the funding and the personnel necessary to use this technology to begin managing this insect instead of merely reacting to it.

f. Man's effects on the incidence of outbreaks

Man has changed the gypsy moth susceptibility of the eastern hardwood forests very little in the past 80-100 years. There have been obvious changes such as the overall reduction in forested area and the introduction of ornamental plantings, but overall susceptibility has not changed. From this standpoint, man has not affected the incidence of gypsy moth outbreaks, but there has been a change in gypsy moth management that has occurred since the 1980-83 outbreak that may influence future outbreaks.

Like fire or other natural disasters, the response to gypsy moth outbreaks typically brings about an acceleration of financial resources to provide immediate short-term relief from the effects of the problem. This was the case with the 1980-1983 outbreak, during which funds were allocated to increase the aerial spraying of insecticides throughout the generally infested area in order to suppress insect populations and to provide temporary relief from tree defoliation and the nuisance caused by the presence of caterpillars. This acceleration of funding has resulted in raising the maintenance level of control response (acres treated) since the outbreak. The table below lists the acres treated and acres defoliated by year from 1973 to the present; and the relationship between the two statistics. For the purpose of this discussion insect activity will be equated with acres of defoliation as these represent the location and extent of damaging levels of the insect.

Acres Treated in Relation to the Previous Season's Defoliation

YEAR	ACRES TREATED (THOUSANDS)	ACRES DEFOLIATED (THOUSANDS)	% OF DEFOLIATED AREA TREATED*
1973	----	1773.8	
1974	253.8	750.9	14.3
1975	48.6	464.5	6.5
1976	42.3	865.4	9.1
1977	19.6	1597.7	2.3
1978	167.0	1259.2	10.5
1979	42.8	643.6	3.4
1980	80.3	5005.0	12.5
1981	350.1	12873.0	7.0
1982	726.7	8171.0	5.6
1983	598.8	2383.0	7.3
1984	512.2	933.0	21.5
1985	518.5	1900.0	55.6
1986	579.6	2413.0	30.5
1987	686.4	[not available]	28.4

*Represents comparison of previous year's defoliation to acres treated the following year; e.g. 1985 treatment (518.5) divided by 1984 defoliation (933.0) = 55.6%.

During the last gypsy moth outbreak the number of acres treated with insecticides rose in response to increases in insect activity (defoliation). This increase, however, was not synchronous with the rise in defoliation. From the table above it appears that control responses (acres treated) are directly influenced by the level of defoliation and that these responses tend to follow, by one season, the onset of that defoliation. Therefore, although the 1980 defoliation of 5005 (thousand) acres represents the beginning of the outbreak, the actual control response to it was initiated in 1981 (350.1 thousand acres). Similarly, the last control response associated with the outbreak occurred in 1984, the year following the outbreak's end.

Perhaps of more significance is that the control response during this outbreak has resulted in elevating to a new plateau the maintenance level of gypsy moth control programs since 1983. As the control response did not keep pace with the rapid rise in defoliation during the outbreak, neither has it been reduced at

the same rate as defoliation decreased. In years since the outbreak (1984) defoliation levels have been as low as 7 percent of those peak levels in 1981. The acreages treated, however, have never dropped below 70 percent of the record treated in 1982 and by 1987 the acreage treated had increased to about 94 percent of the 1982 levels. As a result a greater proportion of the defoliated area has been treated every year since 1984, than in recent memory.

Since 1984 the number of acres treated and the amount of defoliation has increased. However, the number of acres treated as a proportion of the acres defoliated has decreased from a record high of 55.6 percent in 1985 to 28.4 percent in 1987. This probably reflects increased insect activity along the leading edge of the generally infested area in Maryland, Pennsylvania, Virginia and West Virginia, and not a return to outbreak conditions over the generally infested area.

g. Effects of increased public involvement on decision-making

The public has become much more aware of and involved in forest management decision-making. This has had positive results as well as deleterious impacts. On the positive side, management decisions are being made in a much more open atmosphere than in the past, and managers find that they must consider a very broad range of interests in making their decisions. The informational transfer that must take place prior to the making of a decision cannot help but improve the relationship between forest managers and the public and improve the overall decisions themselves. From a negative standpoint, public involvement and reaction to possible management alternatives in dealing with gypsy moth are beginning to result in the use of less than optimum tactics, the avoidance of certain tactics altogether regardless of their efficacy, cost and safety, and is placing managers in the position of reacting (or "proacting") to the public rather than making the appropriate decisions (see discussion under "Limitations imposed by laws and policies"). Decision-making relative to a natural (and public) resource is difficult, but it must be emphasized to the decision-makers that making these decisions is their responsibility, not the responsibility of committees of the public.

h. Forest health vs. pest-caused impacts and treatment risks

The gypsy moth is an interesting social and political insect. The public becomes very excited about its presence and impacts in their backyards and, through Congress, demands and receives action in these areas from their States and the Federal Government. In the recent history of gypsy moth programs, very few residential areas have NOT received treatment under public programs because of public-perceived risks of treatment. For the most part, the public accepts the minimal treatment risks rather than face the impacts of the pest. The forest situation is completely different.

At first, the public is not concerned or even aware of gypsy moth-caused impacts in the forest environment. They become aware, but only from a curiosity standpoint, when large-scale defoliation begins to appear. They do not become concerned about impacts in the forest until the pest begins to affect their use of the forest (i.e., recreation, aesthetics, etc). The final stage of concern about the forests is tree mortality when it begins to appear. Concern seldom involves the value of losses, merely the fact that damage has occurred. From this perspective, the forest managers seem to be the only people with great concerns about the value that has been lost. The only time the public is

concerned about dollars in regard to the gypsy moth is when they must pay to have their properties treated or when they must pay to have dead trees removed. In forested situations, the public seems to feel that the cost of treatment or prevention is not a consideration, but something that the managers have an obligation to carry out and they assume that sufficient funds are available to redeem this responsibility. Also in the case of forests, concern about treatment risks is different from these same concerns in residential areas.

It is interesting to note that, with a few exceptions, there appears to be more (vocal) concern about the possible impacts of the insecticides used in gypsy moth control projects on the forest ecosystem than there is about the effects of these same materials applied at the same dose rates in populated areas. Perhaps this is a function of managers reactions to the public (environmental groups) as opposed to the desires of the majority of the public. Environmental groups have basically given up dealing with the majority of the public in trying to influence residential treatments because they seldom are able to convince enough people that the same material they can buy in the hardware store to dust their tomatoes with will cause cancer and birth defects if it is applied from the air (at much lower dose rates) to control gypsy moth. Forest managers and State governmental officials though are a ripe target. They have discovered over time that these types of people will bend to their desires if only to avoid a confrontation and possible court action and shut-down of projects. This situation has a deleterious impact on the ability to properly and effectively manage the gypsy moth to maintain the health and vigor of the forests.

i. Land ownership patterns of frequency and intensity of outbreaks

Through the 1980-83 outbreak, there is no evidence to suggest that ownership has any influence on the frequency of gypsy moth outbreaks. Intensity differs by ownership, as much of the residential property but relatively little of the forested acres under public ownership have been protected under the existing Federal and State policy. The changes mentioned in management strategies throughout this report may show a change in the future. As discussed, small scale IPM approaches to gypsy moth management have been initiated on some NF and NPS lands during the past two years. Data will continue to be collected on the effects of these IPM programs on these sites over time, and might very well show that during the next outbreak, these sites either did not go into outbreak or the impacts were much less serious. Also, data will be collected in the new Appalachian IPM Demonstration Project and will possibly show this same effect.

<u>Recommendations</u>

1. Further analysis needed

   There is always a need for additional analysis

2. Added information needed.

   Reliable outbreak predictors
   Improved microbial insecticide formulations
   Biotechnology and genetic engineering
   Silvicultural methodology
   Fine-tuned hazard and risk rating models
   Improved survey methods, especially at low population densities

Improved aerial application technology (including insecticide efficacy and efficiency)
Sound F1 sterility technique (including a competitive strain of the insect, improved production methodology, improved application techniques and improved evaluation techniques)
Evaluation of Luretape
Development of an aerial application expert system
Standardization of pheromone traps for different insect population density levels

3. Actions needed now

1. Change Forest Service policy and philosophy to assure that the pest is managed rather than the effects of the pest. Work with the States to effect this same change.
2. Develop the committment (and the funding and personnel needed) to truly deal with this pest in an integrated manner
3. Develop improved survey methods for low level population densities
4. Develop improved microbial insecticide formulations
5. Develop fine-tuned hazard and risk rating models
6. Improve aerial application technology
7. Evaluate the utility of the F1 sterility technique in the leading edge areas
8. Evaluate the effectiveness of Luretape in the leading edge
9. Develop an aerial application expert system
10. Evaluate the effectiveness of the use of combination treatments in the leading edge and generally infested areas

4. Actions needed within 5 years.

1. Develop reliable outbreak predictors
2. Develop comprehensive public education programs concerning the gypsy moth
3. Biotechnology and genetic engineering of the gypsy moth and the various microbial and viral control agents
4. Evaluate effectiveness of silvicultural management strategies
5. Have in place true integrated approaches to dealing with this pest

*

EASTERN SPRUCE BUDWORM

D. R. Kucera

Major Pest: Eastern Spruce Budworm, Choristoneura fumiferana(Clemens)

Ecosystems and Geographic Area: The spruce budworm occupies close to 200 million acres of boreal forest in eastern North America, this report covers roughly 14 million acres in the United State -- 10 million acres in Maine, New Hampshire, Vermont, and New York and four million acres in the Lake States, including Michigan, Minnesota, and Wisconsin (See Table below). Red spruce and balsam fir are the major timber types in the New England States, while white spruce and balsam fir are the major susceptible timber types in the Lake States. In the New England States, stocking frequently exceeds 120 ft^2/acre basal area while in the Lake States, it rarely exceeds 100 ft^2/acre.

Distribution: Occurs in the Eastern United States from Virginia to Maine and westward through Minnesota.

Preferred Hosts: Balsam fir, followed by red spruce, white spruce, and black spruce. Other species, such as eastern hemlock, larch, and pines, are also attacked when near preferred hosts.

Host Vegetation: Area of spruce fir by ownership (X 1,000 acres) in the Eastern U.S.*

	Public	Private Industrial	Private Nonindustrial	Total
Maine	330.2	4,491.2	2,949.1	7,770.5
Michigan	581.4	226.2	448.5	1,256.1
Minnesota	1,408.2	150.1	384.3	1,942.6
New Hampshire	93.8	390.6	151.5	635.9
New York	97.3	157.8	469.0	724.1
Vermont	44.4	97.6	624.4	766.4
Wisconsin	317.5	86.2	337.8	741.1

* From: Recent Advances in Spruce Budworms Research Proceedings of the Canusa Spruce Budworms Research Program, 1985, p. 427.

In addition to the major host type, there is a considerable amount of acreage of less preferred species such as larch, hemlock, and pine which are associated with spruce/fir. When these lesser species are added along with mixed hardwood--spruce/fir, the acreage comprises close to 17 million acres.

Outbreak Cycles and Triggers: One of the first outbreaks recorded in the United States occurred in Maine about 1807. Another followed in 1878. Again from 1910 to 1918, not only was the outbreak recorded but also loss of spruce and fir as well (27.5 million cords: Craighead, 1923). Since then, outbreaks have been recorded periodically; mid 1940-1950's, and early 1970's through the mid 1980's.

The collapse of the 1940's-1950's outbreak was attributed to two factors. First, there was a significant buildup of parasites and predators. Second, unseasonably cold weather in 1959 (4-5 degrees below normal) impacted the insect so that, at higher elevations, it was not able to complete its life cycle (Blais, 1975).

From here on I will discuss the current outbreak (1974-1984). As cited by several entomologists (McClean, 1980), balsam fir normally begins dying after 3 to 5 years of defoliation and spruce 5 to 12. There is one exception, eastern hemlock often dies with only one heavy defoliation. After defoliation ceases, trees may continue to die for several years. This is characteristic of the current outbreak which subsided in 1985.

Any stress, whether defoliation, drought, late spring frost, etc. can cause a tree to die. However, defoliation hastens mortality when it occurs in concert with other stresses. The two most significant triggers in the current outbreak were extensive expanses of mature, overmature spruce-fir at very high stand density (up to 10,000 trees/acre) and a series of warm dry springs, especially in the 1970's. Hardy (1980) has also postulated that infestation foci develop first in mixed-wood type forests of high hardwood content in which spruce occupies a prominent position. Mature-overmature trees also produce more nutritious foliage and flowers. In addition, forest insect outbreaks commonly occur in stands that have passed peak efficiency in biomass production (Wallner, 1987). This is expecially true of the eastern spruce budworm. For example, after the 1910-1918 outbreak, it was hard to find a budworm in Maine until the seedlings that survived the outbreak reached maturity in the mid 1940's. Another factor which aided the present outbreak is the strong flying ability of the budworm. In 1976, mass flights of moths were so heavy they were detected on radar. One flight in Eastern Canada was estimated at one-half mile wide and 20-30 miles long. This ability to occupy new forest areas en masse aids in damaging vast areas of forests and stressing them such that trees are killed quickly. (Table 1, Footnote 2).

Attack Behavior Damage: In the spring, the newly emerging budworm larvae are very small and difficult to find because they bore into and feed on needles or expanding buds. Larvae can cause severe damage to the expanding buds, and both male flowers and cones are also fed upon. As the larvae grow, needles are severed at the base and left hanging in a thin silken web. The severed needles turn brown, giving the defoliated tree a scorched appearance.

Early in an epidemic, defoliation is usually most noticeable in the top portion of the crown. As the epidemic progresses, larvae may scour the tender bark near branch tips and may also mine the pith. In outbreaks of short duration (1-2 years), the top 10-20' of the trees are often killed.
In longer outbreak periods, balsam fir are killed first (up to 100 percent) and eventually up to 50-75 percent of the spruce. The predominant species attacked in Maine are balsam fir and red spruce.

Current Situation as of June 30, 1987: Outbreaks in the eastern United States can be divided into two major areas, the Lake States and the State of Maine. In

Maine, the current outbreak covers approximately 600,000 acres (8 percent infested) which is down from 6 million acres in 1983 (75 percent infested). Due to the Maine outbreak, several hundred thousand acres of timber were harvested prematurely to reduce loss. In addition, several hundred thousand more acres were killed. In 1983 alone, loss was estimated at over 4 million cords. Though the outbreak has subsided, spruce trees that were stressed by defoliation continue to die. In brief, this outbreak started building in the late 1960's, peaked in 1977-78 (8,300,000 acres infested), and began a rapid decline. Since 1986, defoliation has been at less than 1,000,000 acres infested and is expected to maintain a continuing decline into 1988. Because of the extensive mortality which occurred in this last outbreak in Maine, the spruce-fir timber type now covers less than 8 million acres. Until much of the dead spruce-fir are replaced, the epidemic is expected to continue at a low ebb.

The current Maine outbreak started in Aroostook County in the northwestern part of the State in the late 1960's-early 1970's. Much of the infested spruce-fir stands were in small clumps, scattered among farms. Gradually, the outbreak spread westward and south until the mid 1970's when the entire spruce-fir type in Maine was infested and the moth had also invaded New Hampshire and Vermont.

As the outbreak moved west, it invaded dense, overmature stands which were pure red spruce, balsam fir, or mixed spruce-fir. Some scientists felt that land managers were "storing wood on the stump" which exacerbated the problem. In other words, over 60 percent of the forested acreage was mature-overmature and by spraying, land managers felt they could maintain a steady supply of wood for their mills. However, the cost of spraying year after year became uneconomical (over $60 million for suppression from 1954 to 1983), so that eventually stands which were unmarketable or too far from markets were "targeted for mortality" or left to the budworm. At this stage (the late 70's - early 80's), only stands of high commercial value were designated for spraying and this new policy continued until the outbreak subsided in 1985-86. Since then with the infestation at a low level, spraying has been discontinued. No commercial spraying was conducted in Maine in 1986-87.

In the State of Vermont which lies west of Maine, the outbreak developed much later (late 70's - early 80's). Here the tactic was to develop an integrated pest management strategy of harvesting budworm decimated stands and treating only high value commercial forests. This policy continues today.

One deviation from the gradual build up and gradual decline of an outbreak occurred in the State of New York. Here an infestation "blew in" in 1975, caused defoliation on 250,000 acres for two years and then promptly subsided.

The Lake States Outbreak

In general, the Lake States outbreak built up in the 1960's, subsided, then in the mid 1970's built back up to where several million cords of wood were lost (Table 2). At present, about 10 percent of the timber type is infested (400,000 acres). However, because there are fewer markets for spruce-fir in the Lake States, more of the wood was left to die on the stump.

Economic Consideration of an Outbreak: Several factors make it easier to utilize spruce-fir in New England. For example, there are over 12 paper mills which utilize spruce-fir in Maine alone. The resource is near the ocean so that products can be sold readily in either national or international markets and the volume per acre is considerably higher than in the Lake States. Because of

this, it is easier to justify protection (less aerial application cost per unit protected). Another factor is the closeness to the major population centers of the country such as New York City, Boston, Philadelphia, etc. This is not so for the Lake States. Although the Great Lakes provide excellent shipping lanes, no real major markets exist close by. The volume of the resource itself is much more scattered, making it harder to protect, more difficult to manage, and costlier to harvest and move to markets. At present, it is cheaper for some paper companies in the Lake States to buy pulpwood from South America than from local sources. For this reason, it is difficult to manage spruce-fir forests for timber production in the Lake States and expect to realize a return on your investment.

Current Control Program: Because of the marked decline of the current outbreak, neither the State of Maine nor the Lake States have conducted large scale treatment since 1985. There is little need for pesticide treatment in the near future unless the outbreak returns. However, should the outbreak return to Maine, treatment would most likely resume. Further, with the losses experienced (over 20 million cords) in this current outbreak, treatment of many of the remaining decadent stands would not be economical. At present, especially in Maine, salvage continues.

Impacts - Acres affected: Since 1974, the acres of merchantable volume loss is estimated at about 500,000 for the State of Maine. In the Lake States, the loss in acreage is estimated at 200,000 and tree loss is continuing. The most complicating factor is that dead timber is scattered and not comprised of pockets of several thousand acres.

(NOTE: 15 cords/acre average loss X 500,000 = 7,500,000 cords.)

Physical Loss: In the New England States, losses from 1974 to 1985 are estimated at 22 to 24,000,000 cords ($1.2 billion)[1/]. In the Lake States, it is approximately 4,000,000 cords.

1/ The average value of a cord of wood delivered to the mill in Maine is $54.00 (L. Irland - personal communication - July 1987).

Use Loss - Recreation, Wildlife, and Aesthetics: Loss is very difficult to estimate. However, the Maine Bureau of Forestry estimates that during May and June alone over 100,000 people visit the spruce-fir area. These visitors are primarily campers, fishermen, canoeists, and sightseers. At $3.00 per visitor, this amounts to $300,000 which is a conservative estimate of user expenditures.

As for endangered species, both the bald eagle and peregrine falcon have been increasing in numbers in spite of suppression. Other potential endangered species in Maine or the Lake States have not been show to be affected by spray projects.

Control Responses: Both chemicals and biological agents were used on the current outbreak (Tables 3-4). For best results in heavy outbreaks, chemical insecticides are more effective in controlling this pest. Towards the end of the current outbreak too much reliance may have been placed on biologicals.

This is due to two reasons; first, there was a lot of public opposition to chemicals, and second, it was better to use biologicals than nothing at all. However, more valuable timber stands may have been saved with chemicals thus giving landowners more time to salvage dead and dying timber and to save trees before losses became irreversible. Use of chemical insecticides against the spruce budworm will not preclude an outbreak. However, it will buy the land manager much needed time if his timber is ready for harvest.

Treatment Options: For insect directed techniques, the materials of greatest potential against the spruce budworm, in descending order, are: chemical insecticides, chemical insecticides + B.t., and B.t. in outbreaks of lesser magnitude (Simmons and Montgomery, 1985).

When considering cost and effectiveness in large scale outbreaks, then chemicals are the insecticides of choice. When environmental concerns are important and spraying is needed, then B.t. would be the material of choice.

Technology Information: At present, we know most of the factors that can ameliorate an outbreak and they are cited in numerous publications and texts. Simply stated, these are:

1) Plant resistant species and increase species diversity.
2) Reduce stocking by thinning dense stands.
3) Harvest stands as they become mature and reduce the rotation age. Harvest overmature stands as quickly as possible.
4) Protect high value stands with insecticides until they can be harvested.
5) Allow unproductive stands to die out thus reducing reservoirs for insect build up.

Sound forest management is critical in reducing the spruce budworm threat. However, it takes time, money, and resources to manage for sustained yield and multistoried stands. In addition, sound management can be costly. The timber industry has already begun accelerated management. However, the above mitigating measures must be continued into the 21st century in earnest. Otherwise, outbreaks will continue along with stop gap measures rather than sound prevention.

Obstacles and Limitations: Through the NEPA process, government agencies are required to include public involvement. In some cases, the public will vote for no action or inaction. Under this circumstance, the conditions for an outbreak will continue. In other cases, government (both State and Federal) agencies may disallow the use of effective chemicals or biologicals. This may reduce the ability to protect our valuable spruce-fir resources.

Perceived Issues: Land managers have become reluctant to use biological and chemical agents when needed for several reasons. First, the preparation of NEPA documents is costly and time consuming. (Should staffing quotas continue to decline, then manpower could be at a critical point). Second, Federal actions are open to public scrutiny and lawsuits. The ease with which Federal programs can be stopped is well known. Last is the fanaticism and increased organization of environmental groups. The environmental group that put nails in trees in Oregon and Texas, in addition to chaining themselves to trees, is an example of the impediments to sound forest management practices. Unless impediments are lifted or reduced, land

managers will continue to be tempted to do nothing rather than "fight the battle." Unless these outlaws are exposed for what they are and unless strong efforts are made to educate the public about sound forestry, our efforts to combat major insect pests will become even more difficult.

One other issue that needs attention is the public's concern that timber is non-renewable and that clear cutting is "bad." To reduce opposition to our programs, forestry practices must be introduced in elementary schools and grammar grades so that people will understand how forestry is similar to agriculture - that crops are planted to be harvested and if not harvested by man, then nature will - via insects and diseases.

Table 1. Acres of Spruce Budworm Defoliation in the Northeastern U.S.- 1974-1986 (X 1,000)

	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986
ME	5,000	7,000	4,000	5,700	7,000	5,900	5,000	4,000	3,800	6,000	5,500	4,800	600
MI	18	166	815	300	300	259	860	161	129	146	192	94	0
MN	750	105	1,200	150	54	150	103	110	127	139	362	307	400
NH	1/	12	100	110	110	70	90	42	39	6	1	0	0
NY	0	0	250 2/	250	0	0	0	0	0	0	0	0	0
VT	1/	0	20	44	62	102	111	96	154	178	0	0	0
WI	28	60	104	140	140	141	439	84	0	20	22	15	0

1/ Light defoliation reported but acreage not given.
2/ This outbreak was the result of a "blowin." Some businesses that left their windows open had to use shovels to remove the moths! Mass flights were reported from Pennsylvania and the New England States.

Table 2. Loss in Cords Due to Spruce Budworm Defoliation in the Northeastern U.S. (X 1,000) 1/

	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985
ME	112	800	915	1,000 2/	1,000	1,000	1,000	2,250	4,000 3/	4,000	4,000
MI											
MN								6/	502	100 5/	
NH							4/				
VT								237		45	94
WI					40						

1/ Loss was estimated @ 15 cords/acre for 100 percent mortality, 7.5 cords per acre for 50 percent mortality, etc. This was done because several states (Vermont, Michigan, Wisconsin, and New Hampshire) reported acres of loss rather than volumes for 1979 to 1983.
2/ Loss based on estimated projections by the State of Maine for 1978 - 1981.
3/ Based on State of Maine Report (1983 -1987). Loss does not include wood that was salvaged.
4/ Heavy tree mortality reported on over 50 percent of the defoliated area. No volume was given.
5/ Losses in the Lake States for 1984 were estimated at 1,761,356 cords per State reports.
6/ There were 485,000 cords reported killed in the Lake States from 1977 - 1982. Losses were not broken down by States.

Table 3. Number of Acres Aerially Treated with Insecticides to Control Spruce Budworm in the Northeastern United States from 1974 to 1983 1/

	1974	1975	1976	1977	1978	1980	1981	1982	1983	1984	1985
MI											2,500
MN	3,500										
NH						750					
NY		3,240 2/									
VT								960	1,712	170	
WI						750	2,000				

1/ The State of Maine is listed separately (See Table 4).
2/ Spruce Plantation.

Table 4. Summary of Past Aerial Spraying for Spruce Budworm suppression in Maine.

Year	Insecticide	Thousand Acres Treated	Total
1954	DDT	21	
1958	DDT	302	
1960	DDT	217	
1961	DDT	53	
1963	DDT	479	
1964	DDT	58	
1967	DDT	92	
1970	Fenitrothion (Accothion)	210	
1972	Mexacarbate (Zectran)	500	
1973	Mexacarbate (Zectran)	450	
1974	Mexacarbate (Zectran)	430	
1975	Carbaryl (Sevin-4-Oil)	496	
	Fentrothion (Sumithion	1,499	
	Mexacarbate (Zectran)	238	2,233,500
1976	Cabaryl (Sevin-4-Oil)	3,460	
	Trichlorfon (Dylox 4)	40	3,500,000
1977	Carbaryl (Sevin-4-Oil)	808	
	Trichlorfon (Dylox 4)	55	
	Acephate (Orthene Forest Spray)	58	
1978	Carbaryl (Sevin-4-Oil)	967	
	Trichlorfon (Dylox 4)	54	
	Acephate (Orthene Forest Spray)	96	
	Bacillus thuringiensis (Thuricide 168)	21	1,137,300
1979	Carbaryl (Sevin-4-Oil	2,543	
	(Trichlorfon (Dylox 4)	97	
	Acephate (Orthene Forest Spray)	110	
	Bacillus thuringiensis (Thuricide 168, 24, 32, 32B)1/	41	2,791,962
1980	Carbaryl (Sevin-4-Oil)	1,013	
	Bacillus thuringiensis 2/ (Dipe)4L)	100	
	Thuricide 16B	100	1,213,262
1981	Carbaryl	1,015	
	Acephate	31	
	Bacillus thuringiensis	126	1,172,692
1982	Carbaryl	684	
	Acephate	47	
	Bacillus thuringiensis	90	820,051
1983	Aminocarb	633	
	Carbaryl	89	
	Acephate	5	
	Bacillus thuringiensis	119	846,382
1984	Mexacarbate	412	
	Aminocarb	37	
	Bacillus thuringiensis	219	668,026
1985	Bacillus thuringiensis	331	
	Mexacarbate	80	410,937

1/Thuricide 24,32, and 328 were applied under experimental use permits granted by the EPA
2/Demonstration project.

Table 5. Maine Spruce Budworm Suppression in Costs, 1954 - 1985

	Acres	Cost	Cost/Acre
1954	21,000	$ 21,000	$ 1.09
1958	302,000	234,936	.78
1960	217,000	191,334	.88
1961	53,000	61,957	1.17
1963	479,000	489,134	1.02
1964	58,000	77,702	1.34
1967	92,000	117,702	1.28
1970	210,000	270,308	1.29[1]
1972	500,000	1,309,887	2.62
1973	450,000	1,177,496	2.62
1974	430,000	1,006,156	2.34
1975	2,233,500	6,214,137	2.78
1976	3,500,000	8,526,580	2.44[2]
1977	922,190	3,034,341	3.29
1978	1,137,300	3,735,000	3.28
1979	2,791,962	11,320,000	4.05
1980	1,213,262	7,381,258	6.08[3/]
1981	1,172,692	7,200,000	6.14
1982	820,051	8,141,006	9.93
1983	846,382	5,724,930	6.76
1984	668,026	4,768,061	7.14
1985	410,937	3,479,565	8.47

1/ Use of DDT ends.
2/ Cost of oil rises.
3/ Use of biologicals begun on large scale.

SOUTHERN PINE BEETLE

Wesley A. Nettleton

MAJOR PEST: Southern Pine Beetle, *Dendroctonus frontalis* Zimmermann

ECOSYSTEMS AND GEOGRAPHIC "AREA COVERED" IN THIS ANALYSIS: Southern Pine Ecosystem in the southeastern United States

BACKGROUND

Distribution and Hosts

The southern pine beetle (SPB) has long been recognized as the most destructive insect pest of pine throughout the southern United States, and is also found in parts of Mexico and Central America. When present in low numbers, the insects attack severely stressed or dying trees or trees infested by other species of bark beetles. Under those conditions, SPB is not economically important. During outbreaks, SPB attacks, colonizes and kills even the most vigorous and healthy trees. Under those conditions, SPB becomes a primary pest (30).

The SPB prefers loblolly and shortleaf pine, but will attack and colonize all species of southern yellow pine, whether in pure pine stands or in mixtures with hardwoods. The latest forest survey data were obtained from the Forest Inventory Analysis groups of the Southern and Southeastern Forest Experiment Stations to determine the acres of susceptible host type in the South. The acres included are only from stands that were classified as pine or oak-pine and in the sawtimber and poletimber condition class. Table 1 lists the acres of susceptible host type by state, while Table 2 lists acres of susceptible host type by ownership class.

Outbreak Cycles

Most major outbreaks last from 3 to 5 years, and occur in irregular cycles of about 7 to 10 years. At times, the numbers of SPB are so low that multiple-tree spots may not be found in specific areas. Nevertheless, this insect is almost always in outbreak status somewhere within its range.

Earliest records of SPB outbreaks date from the 1750's. Moravian settlers in the North Carolina Piedmont noted the "loss of many pines near Hope" (22). South Carolina plantation owners also recorded widespread losses of pines in the early 1800's. Several outbreaks were reported in 19th century. A summary of outbreaks since 1882 is listed in Table 3 (30).

Table 1.--Acres of susceptible host type by state.[1/]

State	Longleaf/Slash	Loblolly/Shortleaf	Oak/Pine	Total
AL	991,178	4,157,090	2,886,942	8,035,210
AR	--	3,440,704	2,134,440	5,575,144
GA	3,330,994	4,807,891	1,986,235	10,125,120
LA	733,360	3,161,070	1,428,747	5,323,177
MS	551,234	2,950,483	2,449,286	5,951,003
NC	406,080	4,002,837	1,647,672	6,056,589
OK	--	643,493	451,096	1,094,589
SC	664,592	3,077,764	980,789	4,703,145
TN	--	915,475	1,012,904	1,928,379
TX	223,270	3,118,149	1,688,913	5,030,332
VA	--	2,221,425	1,234,709	3,456,134
TOTAL	6,880,708	32,496,381	17,901,733	57,278,822

1/ Acreage figures are for the sawtimber and poletimber classes only. They were obtained from the Forest Inventory Analysis Groups of the Southern and Southeastern Forest Experiment Stations.

Table 2.--Acres of susceptible host type by ownership class.[1/]

State	National Forest	Misc. Federal	State & Private	Total
AL	407,180	145,629	7,482,401	8,035,210
AR	1,049,044	79,430	4,446,670	5,575,144
GA	211,562	369,014	9,544,544	10,125,120
LA	376,686	118,359	4,828,132	5,323,177
MS	735,700	233,131	4,982,172	5,951,003
NC	227,632	163,795	5,665,162	6,056,589
OK	136,801	65,911	891,877	1,094,589
SC	345,293	190,885	4,166,967	4,703,145
TN	180,957	148,714	1,598,708	1,928,379
TX	475,084	68,912	4,486,336	5,030,332
VA	197,036	82,297	3,176,801	3,456,134
TOTAL	4,342,975	1,666,077	51,269,770	57,278,822

1/ This table includes acres of pine and oak-pine sawtimber and poletimber only. They were obtained from the Forest Inventory Analysis Groups of the Southern and Southeastern Forest Experiment Stations.

Table 3.--Extent of, or losses due to, southern pine beetle outbreaks in the South since 1882[1]

Date	General location	Volume loss, or area of infestation
1882	Texas	Unknown
1890-92	Central Atlantic States	75,000 sq. mi.
1902-05	North Carolina, Georgia	Unknown
1907-08	Virginia	Unknown
1910-12	Entire South	Unknown
1913-16	Tennessee, Virginia	200 sq. mi.
1920	Entire South	117,000 MBF
1922-24	Entire South	Unknown
1926	Texas	Unknown
1929	North Carolina, Virginia	Unknown
1931-32	Entire South	Unknown
1937-38	Virginia	Unknown
1939	Texas	Unknown
1949-51	Texas	200,000 MBF
1952-55	Alabama	4,330 MBF
	Mississippi	75,000 MBF
1957-58	South Atlantic	53,200 MBF
	Coastal States	138,600 cords
	Louisiana	Unknown
	Mississippi	1,204 MBF
	Texas	Unknown
1958-69[2]	Texas	43,000 MBF
1971-76[2]	Entire South	6,029,083 cords
		2,085,805 MBF
1979-80[2]	Piedmont	2,277,754 cords
		566,322 MBF
1981-86[3]	Texas, Louisiana	5,353,616 cords
	Mississippi, Alabama, Georgia	2,390,089 MBF

[1]Data to 1960 from Thatcher (29)

[2]Data from 1960-1980 from Price and Doggett (22)

[3]Data from 1981-1986 from personal communication with Michael D. Connor, Loss Committee Assessment Chairperson, Southern Forest Insect Work Conference.

Attack Behavior

SPB attacks on pine are governed by chemical attractants and inhibitors produced by the beetles and the attacked trees (21, 32). Female beetles attacking a tree produce an attractant pheromone that mixes with resin odors from the tree to draw in other flying beetles. If sufficient numbers of flying beetles respond to the attractant pheromone, even the healthiest trees will be successfully colonized (30).

Two distinctly different processes are involved in expansion and spread of a SPB outbreak. These two processes are spot growth and spot proliferation. Spot growth describes the rapid expansion in size of single SPB spots, most often from April through November. Spot growth occurs when adult beetles emerge from dead and dying trees within an infestation and attack uninfested trees on the edge of the same infestation. This attack behavior is controlled by the pheromone mentioned above. During the warm months, spot growth may take place rapidly in the absence of control (30).

Spot proliferation describes beetle dispersal activity when new spots are started, usually in the spring and fall months. Few new spots are initiated during the summer. From October to April, emerging beetles commonly fly from existing spots to start new spots. These new infestations often do not become evident until the early summer (30).

CURRENT SITUATION

Status of SPB Outbreak

The current outbreak began in 1982 in Texas, and eventually affected the majority of the Southeast. In 1985, the epidemic resulted in the most costly summer losses caused by the SPB in recorded Texas history. By mid-July, the number of SPB spots in Texas had already surpassed the highest annual number ever recorded -- this with months of peak beetle activity still remaining. By October 1, 1986, three States (Texas, Louisiana, and Mississippi) tallied nearly 80,000 separate infestations involving 1 billion board feet of timber.

In 1986, the outbreak subsided somewhat in Texas, but continued to rage at record levels in Louisiana and Mississippi. Meanwhile, there was a dramatic increase in the number of spots in Arkansas, Alabama, Georgia and South Carolina. Significant beetle activity was also reported from North Carolina and Virginia. Table 4 outlines the situation in more detail for the States involved (30).

The current outbreak affected 15.4 million acres in 1985 and 26.4 million acres in 1986 (31). Based on the figure from Table 1 of 57.3 million acres of susceptible host type, the SPB occupied 27 percent of the habitat in 1985 and 46 percent in 1986.

In 1987, SPB populations have continued to decline in the Gulf Coastal Plain States. Activity has remained high in north Mississippi and Alabama, central Arkansas, the mountains of Georgia, and in the Piedmont of North Carolina.

Table 4.--Estimated number of SPB infestations from October 1, 1984 to September 30, 1986

State	National Forests		Other ownerships		Total	
	1985	1986	1985	1986	1985	1986
Louisiana	4,535	4,402	16,000	15,321	20,535	19,723
Mississippi	2,538	3,724	1,400	6,218	3,938	9,942
Texas	5,885	2,143	8,930	6,395	14,815	8,538
Georgia	500	778	649	15,021	1,149	15,799
Alabama	410	1,608	1,362	6,518	1,772	8,126
South Carolina	117	394	2,643	7,015	2,760	7,409
Virginia	-	0	-	839	-	839
Florida	-	0	-	29	-	29
North Carolina	-	53	-	6,500	-	6,553
Arkansas	0	160	435	5,269	435	5,429
Totals	13,985	13,262	31,419	69,125	45,404	82,387

It is difficult, at best, to predict SPB population levels for the next few months, let alone years, but the outlook for 1988 looks promising. Losses in 1987 have not approached previous years and it is anticipated that fewer SPB projects will be funded in the upcoming year. However, SPB populations will certainly build up within the next few years and another outbreak cycle will commence.

Causes

The pine stands that grow in the south today probably bear little resemblance to the natural forests that existed throughout most of the coevolution of southern pines and the SPB. Much of today's forest resulted from natural seeding and planting on abandoned agricultural lands from 1930 through 1950. Young stands grew rapidly, but with little management. Insect problems developed and intensified as stands became crowded and vigor declined (3). During recent decades, SPB populations have fluctuated rapidly, with an apparent trend toward increasing severity of damage (9). The magnitude of the fluctuations suggests that the system is in a state of imbalance, perhaps due to the abundance of host species. Given time and no interference from people, the system would reestablish an equilibrium through reduction of the pine component of forests. But this process would be counter to the goals of forest managers, many of whom want to achieve maximum productivity of softwood timber from southern forests (12).

Research results indicate that SPB epidemics can be attributed to one or more of the following factors: 1) favorable environmental conditions such as warm weather or lack of predators, and 2) an increase in susceptibility of forest host types.

There are two important changes in forest conditions over the last three decades that have contributed to the severity of recent epidemics: 1) pine stands have become more densely stocked, and 2) pine stands have, on average, become older.

These changes in forest resource characteristics mean that food and habitat for the SPB have been greatly enhanced over the years.

Data from forest surveys of the South indicate that acreage of pine and pine/hardwood type was about 100.9 million acres in 1952, and has since fallen to about 88.9 million acres in 1985. Volume lost from decreases in pine forest types has been more than offset by increased volumes on the fewer acres remaining in pine.

Stocking density (volume per acre) of pine forests in the south has significantly increased on national forest lands and has increased even more on all other ownerships since 1952. Therefore, while total pine acres have been falling, density has dramatically increased. Increased density is thought to be an important contributing factor in the current outbreak (14).

Little data exist concerning the average age of pine stands on all ownerships. However, sawtimber volume can be used as a proxy for age. The volume of softwood classified as sawtimber has increased dramatically since 1952. Sawtimber volume almost doubled between 1952 and 1977. Sawtimber volume has increased more than total volume. Age class distributions on national forests clearly indicate that acreages are unbalanced toward older age classes. Older stands of larger trees are thought to be another important contributing factor in the current outbreak.

The foregoing reasons, while not conclusive, may explain the cause of the recent SPB epidemic in the Midsouth. National forest and Forest Survey data indicate that pine forests in the south have become older, more densely stocked and therefore more susceptible to SPB attacks.

Preliminary projections of softwood volumes in the south through the year 2000 indicate that stand densities will continue to increase. Therefore, future outbreaks are likely to occur (14).

Current Control Program

Direct control methods - cut and remove, cut and leave, cut and hand spray, and pile and burn - provide the last line of defense for protecting the pine resources from excessive losses once infestations are in progress. Active spots are treated as rapidly as possible. Cut and remove (salvage removal) is the preferred and most commonly used alternative. However, there were periods where, due to poor market conditions or the large number of spots, land managers were not able to sell all of their infestations in a timely manner. Consequently, a significant number of spots were treated by the cut and leave technique. Table 5 summarizes the acres treated by each control method.

Upon the completion of SPB biological evaluations, proposals are submitted for funding SPB Suppression Projects. Table 6 summarizes the projects funded by Forest Pest Management (FPM) in Fiscal Years 1985 and 1986.

Table 5.--Estimated number of acres by treatment during Fiscal Years 1985 and 1986.

State	National Forests		Other ownerships		Total	
	Cut & Remove	Cut & Leave	Cut & Remove	Cut & Leave	Cut & Remove	Cut & Leave
Louisiana	26,694	6,332	77,000	21,000	103,694	27,332
Mississippi	6,570	600	2,075	1,383	8,645	1,983
Texas	9,501	15,191	32,200	15,200	41,701	30,391
Georgia	603	0	18,043	0	18,646	0
Alabama	933	720	6,035	14	6,968	734
South Carolina	100	0	15,989	0	16,089	0
North Carolina	-	-	387	0	387	0
Arkansas	-	-	3,292	360	3,292	360
Totals	44,401	22,843	155,021	37,957	199,422	60,800

Table 6.--Funds used for SPB suppression in Fiscal Years 1985 and 1986.

National Forests	1985		1986	
	I&DC[1/]	SSF[2/]	I&DC	SSF
AL	--	--	132,613	179,227
Ouachita (AR)	--	--	1,032	--
Chattahoochie/Oconee (GA)	7,161	24,347	70,258	17,161
Kisatchie (LA)	1,042,350	796,000	459,806	934,819
MS	154,826	104,000	147,422	146,824
Francis Marion/Sumter (SC)	--	--	49,854	27,641
TX	3,365,062	602,000	850,241	93,858
TOTAL	4,569,399	1,526,347	1,711,226	1,399,530

States	Federal[3/]		Non-Federal[4/]	
	1985	1986	1985	1986
AL	50,000	250,000	72,000	360,000
AR	--	75,873	--	108,033
GA	--	166,470	--	183,760
LA	283,169	342,528	316,831	300,000
MS	43,419	200,000	62,481	287,805
NC	--	45,383	--	60,159
SC	15,000	165,000	20,714	227,856
TX	339,654	434,641	509,481	651,963
TOTAL	754,000	1,679,895	981,507	2,179,576

1/ Insect and Disease Control funds from FPM.
2/ Salvage Sale funds from Timber.
3/ Funds provided by FPM.
4/ Matching funds provided by State government.

IMPACTS

In the most general sense, SPB kills trees. SPB-tree related death triggers a chain of cause-and-effect relationships that affect a large number of activities or values including timber, hydrology, recreation, aesthetics, wildlife, and fire (15). During the current outbreak there were 15.4 million acres in 1985 and 26.4 acres impacted in 1986 by the SPB (31).

Timber Impacts

When a SPB spot occurs, harvested volumes will be reduced. This reduced volume is due to either unsalvaged merchantable trees, harvesting trees ahead of schedule, or both. There may also be an impact on the stand replacing the one killed by SPB.

The volume of timber lost in the current epidemic will exceed any previous outbreak when all the loss figures are finally submitted. Based on figures from the Southern Forest Insect Work Conference Loss Report, between 1983 and 1986 there have been an estimated 3.8 billion board feet killed by SPB.

Other Impacts

The hydrologic impacts of SPB are not usually significant. Generally, water yield increases as vegetation decreases. SPB may temporarily increase water yield by killing vegetation and reducing transpiration and the amount of precipitation intercepted by healthy pines. However, these increases will diminish as vegetative cover returns. Water quality is unlikely to be affected as erosion and sedimentation are not increased significantly by overstory removal.

When SPB attacks a high use recreation site, recreation impacts occur. Tree death results in reduced shade and screening and leaves unsightly dead snags. These snags create a safety hazard to visitors. The cost of removing or at least felling the dead trees and visitor dissatisfaction from the loss are potential economic impacts. If SPB spots become numerous or large enough this impact alone may justify a control program.

Studies indicate that SPB generally has a positive impact on wildlife, either providing a food source, most notably for woodpeckers, or increasing the edge habitat. Impacts would vary by species. Wildlife preferring older growth, climax-type forests with an open understory, would be adversely affected in large beetle-killed areas. Wildlife preferring early successional plant communities with large amounts of forage would benefit as the overstory trees are killed by the SPB. Cavity nesting species and wildlife that forage insects on standing dead trees would benefit. Raptors may benefit by the increase in perch trees while their prey would not. The populations will eventually stabilize. Future wildlife populations will depend on the land use following the outbreak. SPB spots increase wildlife diversity, but the impact will more than likely be small unless losses are substantial.

The deterioration of a stand killed by SPB causes an aesthetic impact. Even though these spots are natural phenomena, they are often perceived as unnatural by some viewers-not only in color, but also in shape and form of the spot. The

sharp color contrast between dying and healthy pines could cause a negative emotional response and be considered unattractive, especially to those who know they are viewing SPB damage. The magnitude of this response will depend on the size of the spots and the distance from which they are viewed. Spots located in the immediate foreground would be the most undesirable. Control actions could mitigate the adverse impacts by limiting the area affected and by shaping the treated area to follow natural contours (15).

Major insect outbreaks which leave large areas of standing dead timber or downed trees can increase fire intensity and difficulty of control. This situation occurred on the Kisatchie Hills Wilderness fire on the Kisatchie National Forest in Louisiana. Between January and July of 1985, 3,891 acres were killed by SPB. Of this acreage, 3,300 acres were treated by cut and leave and 591 acres consist of standing dead timber. On April 12, 1987, a lightning-caused wildfire burned through the area, consuming 7,500 acres and costing over $500,000 to suppress. Even then it was determined that the factor which contributed most to the intensity of the fire was the 30 year absence of prescribed burning. The large acreage of felled SPB-killed trees increased the difficulty of building hand-fire lines. The increased fuels and danger from the standing snags significantly increased the safety hazards and contributed to the fire intensity and rate of spread. However, generally fire impacts may be ignored in management decisions as the majority of SPB spots are small and dispersed throughout the forest.

Monetary value of losses

Economic losses caused by SPB can be substantial. Perhaps the most obvious (and easiest to measure) losses relate to timber values. Annual losses reflect the highly variable population levels of SPB. Average annual losses exceed $17.4 million. During the past 25 years, annual losses have ranged from less than $1 million to over $120 million (see Table 7). Notice that the greatest dollar loss to SPB has been in 1985 and 1986.

CONTROL RESPONSES

In response to the latest SPB outbreak, the Forest Service and State organizations began a control program to minimize losses of forest resources, including commercial timber and red-cockaded woodpecker habitat. Control focused on containment of individual spots as opposed to areawide population control. Control work was carried out by using the four recommended control techniques; cut and remove, cut and leave, cut and hand spray, and pile and burn. For a full explanation of control techniques, see the section on treatment options.

If no control were taken on the SPB infestations a substantial additional acreage of pine would have been killed. Repeated SPB outbreaks would dramatically change areas predominately in pine to a mixture of pine and hardwood trees. Many pine acres would have been converted, both naturally and by man, to a less productive use. Prescribed burning would likely increase for site preparation and reducing the fire hazard on SPB-killed acres. The increased use of fire on SPB-killed areas would increase herbaceous growth, but lower species diversity. Locally, the risk of an outbreak would be temporarily reduced following an SPB attack as the older, slower-growing trees are placed by younger, more vigorous ones (30).

Table 7.--Southwide recorded economic losses caused by the southern pine beetle, by year[1]

Year	Estimated Losses	Year	Estimated Losses
1960	$ 380,759	1973	$43,245,149
1961	666,584	1974	43,081,356
1962	15,116,265	1975	30,836,309
1963	702,075	1976	32,407,239
1964	849,478	1977	14,912,841
1965	1,578,267	1978	1,676,278
1966	1,563,217	1979	68,951,596
1967	737,872	1980	75,146,683
1968	2,294,298	1981	23,727,910
1969	2,180,566	1982	8,340,864
1970	2,328,309	1983	23,514,781
1971	2,559,703	1984	12,407,599
1972	25,977,049	1985	120,968,655
		1986	100,807,009

[1]Data for 1960 through 1980 from Price and Doggett (22). Data from 1981 through 1986 from personal communication with Michael D. Connor, Loss Assessment Chairperson, Southern Forest Insect Work Conference. Values are current dollars (i.e., 1960 dollars represent value in 1960).

Due to the current stand conditions and cyclical nature of SPB populations, there is probably very little that could have been done to preclude this outbreak. Perhaps if forces could have mobilized faster in an effort to control the spots, providing timber markets were available, the overall impact could have been reduced.

The first step in a preventive approach involves the recognition of conditions favoring infestation incidence and spot growth. Several methods are available to rate the relative susceptibility of stands to SPB attack (16). SPB hazard rating has been initiated or scheduled for most national forests and also is being implemented on many state and private lands.

SPB hazard ratings provide useful information to prioritize need, scheduling, and timing of appropriate treatments. The potential for SPB spot initiation, growth, and volume loss is greatest in high-risk stands. These stands should receive earliest management attention. The probability and potential for losses are less in moderate- and low-risk stands.

Successful management of the SPB problem requires (1) long term silvicultural treatment of the forest to lower stand susceptibility, (2) continuous monitoring, (3) aggressive suppression action during initial stages of an outbreak and (4) filling information voids relating to SPB.

Increased preventive measures southwide would reduce susceptibility and losses to this insect pest. These actions would reduce the acreage of old and dense stands that are vulnerable to the beetle. The actions that would have the most effect are: 1) reducing the acreage in mature and overmature timber and 2)

lowering rotation ages. Other actions that would help lower susceptibility are: 1) thinning dense stands, 2) changing species, and 3) using hardwood barriers. Over time, these actions would achieve and maintain healthy, vigorous forests. However, other considerations often do not permit the implementation of these actions to the extent desired. Thinning dense stands still offers the most promise and can be implemented immediately.

Many of the recommended actions require changes in management philosophies and some may require changes in current national forest land management plans. These changes should be considered when plans are revised or amended. There will be some conflicts with other resources. The tradeoffs must be analyzed and decisions must be made as to which and how much of the actions to accomplish. We must remember that SPB outbreaks are sporadic and will continue to occur if forest conditions are maintained that are conducive to catastrophic outbreaks. Outbreaks of the magnitude of the last 3 years cause more conflicts with other resources than a planned program of maintaining healthy, vigorous forests.

The current and previous outbreaks can be tied to stand conditions. Large acreages of host types exist, and as do large acreages of older age classes. <u>These conditions will continue to exist for a long period of time. Therefore future outbreaks of SPB are likely to occur</u>. Over time conditions can be modified to reduce seriousness of outbreaks (<u>14</u>).

TREATMENT OPTIONS

Control programs that involve both preventive and remedial measures are being encouraged. Depending on the value of the resource threatened, the spot size and accessibility, the objectives of the landowner, and the season, the control strategy may be to minimize timber losses, to maximize beetle mortality, or to let nature take its course. Indeed, many spots may go untreated if the likelihood for additional losses is small or the landowner places little or no value on the threatened trees (<u>4</u>).

At present, forest managers can choose from one of the four recommended control methods that include (1) cut and remove, (2) cut and leave, (3) cut and hand spray and (4) pile and burn.

Cut and Remove

Cut and remove is the name of the technique emphasizing prompt removal of logs with beetle-infested bark intact. The objective of this technique is to reduce beetle concentrations in treated stands (<u>6</u>, <u>18</u>). Removal of infested trees and an adequate buffer strip prevents spots from spreading. The inclusion of a buffer ensures the removal of freshly-attacked pines that were overlooked or became infested after the spot was first evaluated and marked. SPB-infested material must be promptly removed to achieve maximum effectiveness: stopping additional spot spread. Because both the beetles and their associated pheromone source are removed from the site, the potential for both spot spread and spot proliferation is minimized.

Managers and owners prefer cut and remove over the other control options because infested trees are removed from the forest and used, giving the landowner some financial return (an estimated $750/acre revenue for sawtimber size trees at an assumed $75/MBF salvage price and 10 MBF/acre). However, removal of individual

spots is not always practical because of inaccessibility, insufficient volume, poor lumber or pulpwood market, and environmental considerations. In addition, cut and remove often takes longer to implement than alternative tactics. Despite these limitations, cut and remove, when properly and promptly applied, remains the most practical and economical control tactic for treating most large, rapidly-growing infestations (28).

Cut and Leave

Cut and leave involves felling infested trees and a buffer strip of uninfested trees so that the crowns point toward the center of the spot. This treatment disrupts spot growth and causes emerging adult beetles to disperse into the surrounding forest. Cut and leave was first developed and recommended in 1929 by St. George and Beal (24). The technique was modified by the Texas Forest Service and is being used increasingly to control spots that cannot be salvaged. It is usually recommended for spots with 100 infested trees or less. In 1979, cut and leave was added to the list of SPB control procedures for which Federal cost-sharing would be available.

Cut and leave is practical, relatively inexpensive, and requires a minimum of labor, equipment, and training. The procedure can be applied soon after spots are detected. Freshly-attacked trees are sometimes difficult to detect during the early stages of attack. Therefore, the major disadvantage is that a buffer strip of green, uninfested trees must be felled around each spot to assure that freshly-attacked trees are included in the treatment. Many landowners are reluctant to sacrifice this buffer if the trees cannot be salvaged. Typically there is a charge of up to $3/tree to fell a tree. Apply this charge to an assumed 100 trees/acre, for a $300/acre cost for this method.

Expanding spots involving more than 100 active trees are more difficult to stop with cut and leave. Breakouts are more likely to occur for spots exceeding 100 active trees.

Cut-and-leave methods were first designed to capitalize on biological limitations of developing beetle broods (20). Low moisture and high temperature in the inner bark area of the felled trees were expected to reduce beetle survival. However, experimental tests of cut and leave did not kill enough beetles to justify its application solely on that basis (11, 13, 21).

Nevertheless, cut and leave remains useful mainly because of another beneficial effect -- when a buffer strip is included, it usually stops the expansion of a spot (20). The biological rationale for spot disruption by cut and leave is based on the way individual spots expand during the summer. Continuous spot growth requires at least three factors: emerging beetles, nearby pine trees, and a source of secondary attractants. Felling the most recently attacked trees eliminates the attractant source (32). The felled buffer strip eliminates nearby unattacked pines, and beetles emerging from the infested trees tend to disperse in the absence of attractants (8).

The fate of beetles that are not killed or removed mechanically has been partially explained by SPB population dynamics research. This research has determined that long-range beetle dispersal normally occurs when temperature conditions are favorable--from November through March. Very little dispersal occurs during the warmer months because of the weakened physiological condition

of the beetles--the stored fat from which the beetles draw energy for flight is lowest during this period (10). Furthermore, certain behavioral responses have long been associated with fat content. Among these are orientation to host material and the very inclination to take flight (1).

The pheromone content of the beetles reaches its peak in the fall, when the beetles are less aggregated. At the same time, sensitivity at the olfactory receptor level appears to increase. During the summer when infestations are expanding, the beetles are less responsive to pheromones (7).

Beetles that are forced by the effects of control to fly farther than the next trees are likely to die (10). The longer that beetles must fly to start a new spot or join an existing spot, the greater the probability that they will die.

In a limited study, beetles were tagged with radioisotopes to determine dispersion distance differences in winter versus summer. Winter analysis of three freshly-attacked spots showed that beetles were able to fly 223 to 1,197 feet from 19 cut-and-topped trees. All of the attacked trees were killed and spot expansion continued into the summer and went inactive. In contrast, during the summer, beetles emerging from seven cut-and-leave trees attacked pines in two spots 33 and 600 feet away. None of the attacked trees were killed (17). This study lends further support to the rationale for cut and leave during the summer months.

There is evidence that greater numbers of predators and parasites of the SPB emerge from SPB-infested trees treated by cut and leave than from standing infested trees during the summer (2).

Cut and Hand Spray

Cut and hand spray is the felling, limbing and bucking of infested trees into manageable lengths and hand spraying with an insecticide. Insecticides may be used to control the SPB in individual trees or small groups of trees. Registered insecticides, lindane and chlorpyrifos, are available for this purpose. Although chemical control is costly and raises some environmental concerns, it may be the best alternative in urban forests, high-value recreational areas and, to a limited degree, in commercial forests when other methods cannot be used.

For inaccessible areas, the cost of felling a tree, bucking and spraying a tree with an approved insecticide averaged $20/tree. With an assumed 100 trees/acre, the total cost for this would be $2,000/acre.

Because of these high costs and environmental concerns, no large-scale chemical, bark-beetle control projects are likely to be undertaken in the South, as was done in the 1950's and 1960's. Nevertheless, a need remains for a fast-acting, effective tactic to reduce SPB populations. To date, only insecticide sprays can assure this level of protection (23, 27). In commercial forests, insecticides are useful for treating small spots during the winter, spots inaccessible to heavy equipment, and for breakouts.

Pile and Burn

Pile and burn refers to the felling, piling, and burning of infested trees. This technique is one of the oldest SPB control methods, and also is one of the most effective when properly done. However, because of high costs and environmental constraints, the practice has been used sparingly in recent years. The bark must be completely burned to achieve control. Vacated trees need not be cut, piled, and burned. For practical reasons, both infested and vacated trees are usually piled and burned to clear the site for regeneration. Because burning can cause wildfires, this technique should be restricted to periods of low fire danger. Also Federal and State air pollution laws must be followed.

The biological rationale for pile and burn is comparable to that for cut and remove and cut and hand spray, i.e., the beetles are destroyed if the infested bark is completely burned. This practice has been largely abandoned, however, because of the labor and logistical problems involved. In most cases, heavy equipment must be used to pile the trees. In wet areas, burning felled trees becomes extremely difficult. In dry areas, the procedure increases the chances of wildfire, and burning must be restricted to days when fire danger is low.

This technique has only been used in the current SPB epidemic when a spot occurs in a young pine plantation. The cost of the treatment varies by timber size class, but would probably average about $150/acre.

Volume Protected by Control

In the 1987 Final SPB EIS (30), appendix D contains an economic analysis of the SPB suppression projects on the National Forests in Texas and Mississippi and the Kisatchie National Forest for Fiscal Year 1985. In review and analysis of the records on control actions an estimate of the current volume of timber protected by the use of the cut-and-remove and the cut-and-leave methods was determined (Table 8). This was accomplished by the use of a SPB spot growth model, developed at the University of Arkansas (25). The model provides short-term predictions of potential tree mortality in SPB infested stands.

Table 8.--Projected volumes protected during Fiscal Year 1985 on the National Forests in Texas and Mississippi and the Kisatchie National Forest using the Arkansas Spot Growth Model.

	Projected Volume Protected	
National Forests	Cut and Remove (MBF)	Cut and Leave (MBF)
Mississippi	22,154	4,055
Texas	38,498	143,657
Kisatchie (LA)	29,940	27,027

The volumes protected by treatment will vary with the intensity of the outbreak and how rapidly the spots are controlled. A further and more complete economic analysis of the current SPB outbreak is currently being prepared and should be available in early 1988.

TECHNOLOGY INFORMATION

Available Technology

Over the past 15 years our understanding of the SPB and the forest in which it occurs has increased substantially. The Expanded Southern Pine Beetle and Research Program and the ensuing Integrated Pest Management R&DA Program for Bark Beetles of the Southern Pines developed many new ways of dealing with this insect and its host (5).

Today, the technology and knowledge exist to reduce the impact or frequency of future SPB outbreaks. The following cultural practices provide the means to produce environmental and biological conditions unfavorable to the attack, spread and population growth of SPB:

* Shortening the rotation age
* Decreasing acreage of mature and overmature stands
* Decreasing stand density
* Favoring most resistant species or changing species composition
* Increasing the use of barriers
* Increasing forest diversity

The problem is that the implementation of these measures is not always possible due to several restrictions placed on the forest manager. The first is the large amount of acreage controlled by the nonindustrial private landowner in the South. These people are a diverse group with a wide variety of management objectives. Timber production, unfortunately, is not not always a primary goal for these lands and, in these cases, losses of trees to SPB spots are of little concern (5). Slow or delayed control action can allow epidemics to get a good start.

Second is the multiple use management objectives of the national forests. Most national forests in the Southern Region contain a disproportionate amount of contiguous, large, and mature pine sawtimber. To have a real affect on future outbreaks many of these stands should be regenerated and the rotation age lowered. However, due other coordinating considerations in the national forest land management plans, such as red-cockaded woodpecker, wilderness, allowable sale quantities, etc., these actions are not likely to be implemented immediately. Efforts will be made to reduce the amount of high- and medium-hazard stands through normal timber sale activities (14).

Another consideration is public pressure, especially on the federal and state agencies, which has resulted in federal laws that mandate a complete assessment of the social, economic, and biological risks and benefits (26). Public involvement in forest land management planning has indicated that many people would like to maintain older age pine. As a result, the rotation age for some pine stands has been extended to 120 years or older. This decision has dramatically increased the susceptibility of these stands to SPB attack. Also,

there have been two court cases involving the Forest Service and environmental groups over the issue of SPB control in designated wilderness areas. These actions and other considerations prompted the Forest Service to prepare a new Environmental Impact Statement for the suppression of the SPB. Based on this document new guidelines have been developed that permit control of beetle spots only after a site-specific analysis has been performed and stringent criteria are met.

Finally, a factor that affects all groups of landowners is the local timber market conditions, both prior to and during the outbreak. Many areas throughout the south have very weak markets for pulpwood. This makes the use of intermediate cuts to maintain healthy vigorous growth a challenge. If thinning schedules are not met, pest problems are likely even with lower rotation ages. Poor markets in the early stages of a SPB epidemic many times lead to delays in control and increased losses.

Additional Technology Needed

In response to the extreme severity of the current SPB outbreak, the Chief of the Forest Service appointed a core team to develop both long- and short-term strategies for the control and prevention of losses from SPB. The team developed a report (14) and among other things identified research and application needs whose solution would further aid resource managers on preventing and/or suppressing the SPB. Following is a brief summary of these needs:

Evaluate and quantify SPB dispersion and the phenomenon of spot proliferation.

Develop techniques and methods to predict SPB population trends and the onset, duration, and collapse of outbreaks.

Improve or develop long-term prevention and control techniques giving priority to economically feasible, environmentally acceptable approaches.

Determine the effect of various silvicultural practices on insect and disease incidence in older stands.

Determine if there is genetic resistance to SPB attack.

Establish a major demonstration project on two national forests to determine the feasibility of intensive silvicultural preventive and control techniques under operational conditions.

Each of these action items has been assigned to groups within the Forest Service. The answers gained from this work should be of major benefit to all land managers in the South.

PERCEIVED ISSUES

Pest management, which should be an integral part of forest management, is often ignored until pest problems appear, usually in serious proportions. Then pest management is based on reaction to a crisis situation, rather than planned within the context of the management of the total forest resource (19).

Currently, integrated pest management (IPM) only gets cursory attention in the majority of the national forest land management plans in the southern region. They state simply that IPM will be used to minimize pest losses and then briefly list several standards and guidelines.

However, the current SPB outbreak has caught he attention of forest planners and there is more attention being paid to the fact that many of the forests have a serious overabundance of mature timber. Some of the action items in the Long- and Short Term Strategies Report (14) should provide some answers.

The national forests and small nonindustrial private landowners will probably bear the brunt of the next SPB outbreak. The reason is that these are the areas where the majority of the older, larger pine sawtimber stands are located. The management objective of forest industry to maximize returns through short timber rotation (25-35 years) should minimize their hazard to SPB (5). Of course, if the outbreak becomes severe enough, like the situation in 1985 and 1986 in the Gulf Coastal Plain, all stands are susceptible to losses.

RECOMMENDATIONS

The demand for timber is increasing in the United States today and with the South replacing the West as the timber-growing center of the nation, there will have to be a substantially greater production from a shrinking land base (5). State Foresters need to continue to make a concerted effort to integrate forest protection into forest management plans. Emphasis should be given to early detection, timely action, and the implementation of preventive techniques to limit the amount of future losses.

On the national forests, the major objective for future work on the SPB should be to complete the action items listed in the report on the long- and short-term strategies and research needs for managing the southern forest to reduce SPB impacts. The core team that prepared the report did a good job of identifying areas that needed attention. The economic analysis on SPB suppression efforts, currently being prepared, may identify additional areas of concern.

Although we are still lacking many answers regarding the SPB, the potential for implementing IPM in forest management is improving (26). By better education of the public and making foresters aware of the opportunities to prevent outbreaks we may make some progress in the coming decades.

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ROOT DISEASES IN WESTERN FORESTS

J. W. Byler

MAJOR PESTS: This analysis covers the major root pathogens in the West. Five of these are responsible for most of the damage:

Phellinus weirii, the cause of laminated root rot.

Armillaria mellea complex, the cause of Armillaria root rot

Heterobasidion annosus, the cause of annosus root disease

Ceratocystis wageneri, the cause of black stain root disease

Phaeolus schweinitzii, the cause of brown cubical root rot

This brief report attempts to describe a number of complex and differing diseases. Consequently, some statements are oversimplifications. Most of the paper addresses root pathogens as a group, and some rather gross generalizations are made.

ECOSYSTEMS AND GEOGRAPHIC AREAS: The coniferous forests of the western United States is the area covered. Most information on root diseases comes from the Pacific Coast and Northern Rocky Mountain regions, so particular reference is made to these areas.

BACKGROUND: All forest types are affected to some degree by root pathogens. Douglas-fir and fir-spruce types are the most seriously damaged. However, damage occurs in localized parts of the ponderosa pine, hemlock-spruce, western white pine, and other types, especially where the major hosts of the pathogens comprise a significant component of the stands. The Douglas-fir and fir-spruce types contain 50.8 million acres (40 percent) of the 128.3 million acres of commercial forest land in the West (Table 1).

All western conifers are damaged by root pathogens. But the major hosts in terms of mortality and volume killed are Douglas-fir and various species of true firs, especially white fir and grand fir.

Root diseases are unique among forest pests because their outbreak cycles are very long, often longer than the host rotation length. The rate of buildup of an epidemic is quite slow in comparison with other forest pests. Many years, sometimes decades, are required for a root disease to go from a low level, endemic condition in a stand to epidemic levels. But once outbreak levels are achieved, high inoculum levels persist throughout the life of the stand, and usually carry over in the form of infected roots and stumps to subsequent rotations. This inoculum results in increased damage in successive stands. Mortality occurs earlier than in the previous stand, and losses are likely to be greater.

Table 1.--Area of commercial timberland in western United States by forest type and ownership.

Forest type	National Forest	Other public	Forest industry	Other private	All ownerships
	----- Ownership -----				
	(Thousand acres)				
Douglas-fir	14,392	5,294	4,957	6,255	30,898
Fir-spruce	13,528	2,701	1,510	2,116	19,855
Ponderosa pine	13,657	4,116	2,214	6,663	26,649
Hemlock-Sitka spruce	8,529	1,401	1,991	945	12,866
Other softwoods	11,778	1,258	1,120	2,624	14,862
Western hardwoods	3,401	3,927	2,068	5,467	16,782
Nonstocked	2,648	849	764	2,127	6,387
TOTAL	67,933	19,546	14,624	26,197	128,299

Compiled from the publication titled "An Analysis of the Timber Situation in the United States, 1951-2030," 1982, USDA Forest Service, Forest Resource Report No. 23.

Pathologists agree that man's activities have set the stage for root disease outbreaks. The activities, especially fire control and partial cutting, have created stands composed chiefly of the major hosts on sites where the hosts are climax. Drought and tree cutting probably trigger root disease mortality. Drought affects tree resistance to root pathogens and leads to accelerated mortality of infected trees. Cutting affects root diseases in several ways: it provides stump surfaces for _H. annosus_ infection; it attracts vectors of _C. wageneri_; and it creates food bases that enhance the ability of most root pathogens to successfully colonize and overcome uninfected trees.

Short-distance spread of most root pathogens is through root grafts and root contacts between infected and uninfected trees. Long-distance spread is relatively rare for most root pathogens. However, two major pathogens have efficient mechanisms for long-distance spread. _F. annosus_ infects freshly cut

stump surfaces by means of airborne spores. _C. wageneri_ spores are introduced into uninfected trees by insect vectors feeding on tree roots.

Tree killing is the most serious consequence of root disease. Root pathogens kill trees directly. They also weaken trees by killing and/or rotting roots. Root-diseased trees are predisposed to attack by bark beetles and to windthrow. Failure of root-rotted trees is a source of hazard to people and property in recreation areas. Butt rot is an important cause of loss in old-growth stands.

CURRENT SITUATION: Information is provided on five different root diseases. They represent unique situations in terms of disease cycle, host preference, and control.

(1) Laminated root rot

(2) Armillaria root rot

(3) Annosus root disease

(4) Black stain root disease

(5) Brown cubical root rot

Other unique root disease situations that are not covered are:

-Port Orford cedar root disease (caused by _Phytophthora lateralis_

-Tomentosus root rot (caused by _Inonotus tomentosus_)

(1) Laminated Root Rot

Major hosts: Douglas-fir, true firs, hemlocks, spruces

Other hosts: Pines, western redcedar, larch, incense cedar

Geographic area: Oregon, Washington, northern Idaho, and western Montana. This disease is found throughout the range of Douglas-fir and true firs in Oregon and Washington (with the exception of extreme southeastern Oregon) and approximately the range of grand fir in Idaho and Montana.

Status: The disease is native to the Northwest. It causes butt rot of old growth. Tree mortality is believed to have increased considerably during the past century as old-growth stands were replaced by young-growth stands of susceptible species by early harvesting and by stand replacement fires. The geographic distribution of the disease is limited, but when present it can be the most damaging of western diseases.

Phellinus mortality is frequently found within a few years following regeneration. Centers become apparent at about 20-40 years of stand age. These centers continue to enlarge at the rate of about 1 foot per year. Rates of mortality in individual stands can be 2-4 percent per year for susceptible species. By 80-120 years of age, stand stocking and volume can be reduced

by50-75 percent or more. Pathologists in the Pacific Northwest estimate that diseased parts of stands average about 50 percent of the expected volume.

The total acreage occupied by the fungus may not be changing greatly. It has been suggested that P. weirii occurs on every section occupied by Douglas-fir in Oregon and Washington except for extreme southwest Oregon. But pathologists believe that P. weirii inoculum and damage are increasing in second-growth stands. A rule of thumb for infected, young-growth stands is that area in mortality centers and number of trees killed can double every 10-15 years. No estimate has been made of acreage increase on a Regionwide basis, but an overall increase in damage appears evident.

Causes: The cause of laminated root rot is Phellinus (Poria) weirii. The severity of damage is increased by events that have brought about the conversion of old-growth stands to young-growth stands while increasing the component of the major host species.

-Many decades of fire control have increased the host complement on sites where those species are climax.

-Partial cutting that opened up the canopy gradually, without significant soil disturbance, favored Douglas-fir and true firs on the same sites.

-Selective cutting of ponderosa pine, western white pine, western red cedar, and other high-value species favored Douglas-fir and true firs.

-Douglas-fir has been widely planted on sites that formerly contained old-growth western redcedar, western hemlock, western white pine, and other species.

-Overstory removal cuts in diseased stands have resulted in many acres of susceptible Douglas-fir and true fir regeneration.

-Wildfires that occurred during the last two decades of the past century and the first two of this one created stands that were heavy to Douglas-fir and grand fir in northern Idaho and western Montana.

-White pine blister rust has removed most of the white pine which would have been a major component in stands that are now Douglas-fir and grand fir.

Other factors that contributed to the current problem are the creation of stumps that serve as food bases for the pathogen, and continuous cropping of host species, i.e., immediate regeneration with host species following a harvest cut.

Control: The only widely applicable control methods are silvicultural. The dominant approach is to favor disease-tolerant species:

-Favor natural or planted species that are tolerant of root disease when regenerating.

-Accelerate harvesting (pathological rotation) to capture volume that would otherwise be lost.

-Favor disease-tolerant species during precommercial thinning.

-Forego intermediate harvests in diseased stands.

-Destroy and regenerate severely damaged precommerical stands.

Some of these treatments can be accomplished during routine stand entries at little or no additional cost. Others, planting for example, increase costs by $200 per acre or more.

(2) Armillaria Root Rot of Mixed Conifers

Major Hosts: Douglas-firs, true firs

Other Hosts: Most other conifers

Douglas-fir and true firs are most commonly damaged. But, all conifers can be killed at an age of less than 20-30 years. Considerable variation in host susceptibility to the Armillaria complex is observed in different locations. At some western locations, for example, ponderosa pine and lodgepole pine are more susceptible than Douglas-fir.

Geographic area: Species in the Armillaria complex are widely distributed throughout the world. The disease has been reported from all western Regions. The coniferous forests of northern Idaho, western Montana, eastern Washington, and eastern Oregon are especially heavily impacted.

Status: Pathogenic Armillaria species are native to the West. But, damage is believed to be greater now than in the past, due to activities that have increased the abundance of the major hosts, decreased host resistance (off-site planting and soil degradation), and increased inoculum. Armillaria commonly affects stands and trees that are also affected by other root pathogens. East of the Cascades in the Northwest and west of the Continental Divide in the Northern Rockies, pathogenic Armillaria species and P. weirii are commonly associated.

In individual stands, mortality begins to appear within a few years following regeneration. The source of infection is infested roots of stumps from the previous stand. Mortality continues around these stumps until the stand reaches an age of 20-30 years. After this age, little mortality is observed in stands west of the Cascades and in pine and larch stands east of the Cascades. Mortality continues in Douglas-fir and true fir stands east of the Cascades and can be extensive. Volume can be reduced by 50-80 percent at rotation. Root disease-caused mortality may also continue beyond age 20-30 in off-site plantings of pine and larch.

The acreage occupied by A. mellea complex is extensive, and probably has not changed greatly during the past decades. But inoculum and damage have increased greatly on infested acres by actions that increase the abundance of the major hosts, stress conifers, and increase the number of stumps. Overall, the disease appears to be on the increase.

Causes: The immediate cause of Armillaria root rot is one or more species in the *Armillaria mellea* complex. The major part of the damage in the Northwest and Inland Empire appears to be due to *A. obscura* = *A. ostoyae*.

Indirect causes are similar to those listed for *P. weirii* (see the next section). In addition, actions such as off-site plantings that stress trees are believed to make Douglas-firs more susceptible west of the Cascades. Stress factors also play a role in Douglas-fir, pine, and larch stands east of the Cascades.

Control: The major means of control of Armillaria root rot, like that for laminated root rot, is silvicultural. Although the two diseases vary somewhat in their host preference, the techniques listed for laminated generally apply to Armillaria root rot. In many Northwest locations east of the Cascades and in the Inland Empire, stand prescriptions must account for the presence of both pathogens.

Practices that stress trees should be avoided. Even the most tolerant conifer species are susceptible to Armillaria root rot when under same conditions. Practices likely to increase diseases include site treatments that reduce soil productivity, harvesting that results in soil compaction, off-site planting, and poor planting techniques.

(3) Annosus Root Disease

Major Hosts: All conifers

Geographic Area: Annosus root disease is important on pines in southern California, the pine forests of eastern Oregon and California, and at other localized areas in the West. It is damaging to true fir forests in California, south-central Oregon, northern Idaho, and elsewhere. It causes extensive butt rot of old-growth western hemlock in Oregon, Washington, and Alaska.

Status: Annosus root disease was present in old-growth stands of the past where it caused primarily butt rot. In young-growth and cutover stands, it is often a tree killer. In pines, the fungus invades and kills the sapwood and cambium at the root collar. In true firs, it acts as a root rotter. Trees not killed directly are often weakened and predisposed to attack by bark beetles.

The disease is increasing as a result of harvesting. Infection centers are started when spores of the fungus land on freshly cut stumps or tree wounds. The centers then enlarge through root-to-root contact between trees. Centers can enlarge and persist for many decades. In some sales in northern California pine forests, 50 percent or more of the stumps formed new centers. In Oregon ninety percent infection has been found in white fir stumps greater than 18 inches.

Causes: *Heterobasidion annosum* (*Fomes annosus*) is the cause of annosus root disease. Different strains of the fungus appear to be rather host specific. One prefers pines and another prefers firs. Management practices have also contributed to disease intensification. Harvesting has created infection courts. Partial cutting and fire control have favored true firs on hazardous sites in California, Idaho, and Oregon.

Control: Stump infection can be prevented by applying borax to the freshly cut surface. The treatment is about 90 percent effective. Stumps are routinely treated in some timber sale areas in the pine forests of California and sometimes treated in other parts of the West. Stump treatment is also recommended where trees are cut in campgrounds and other high-use recreation areas.

(4) Black Stain Root Disease

Major Hosts: Douglas-fir, ponderosa pine, lodgepole pine, pinyon pine

Other Hosts: Other conifers

Geographic Area: Black stain root damages conifers at many locations in the West. Serious infestations include:

Young-growth Douglas-fir stands of coastal Oregon, California and Washington.

Young sawtimber ponderosa pine stands in northern and central California.

Pinyon pines in Arizona, California, Colorado, Nevada, New Mexico, and Utah.

Status: The disease is most common in young-growth stands that have been disturbed by man. One reason for this is that disturbances attract insect vectors. Road building and precommercial thinning, for example, weaken trees and attract root-feeding bark beetles and weevils that carry fungus spores. The disease can be very damaging, especially in precommercial Douglas-fir stands on the Oregon Coast Range. It appears to be increasing.

Causes: Black stain is a vascular wilt type of disease. *Ceratocystis wageneri* (*Verticicladiella wageneri*) is the cause. There are several strains of the fungus, one of which normally infects Douglas-fir and another which affects pines. Contributing factors include road building, precommercial thinning, and soil compaction.

Control: Black stain root disease management strategies are aimed at treating infested areas and preventing the formation of new centers.

Treatments for infested stands include:

--favoring nonhost species in centers and

--clearcutting centers with a buffer zone around centers to stop root-to-root spread of the pathogen.

Prevention of new centers is accomplished by minimizing site disturbance, tree injury, and vector attraction:

--avoiding tract or logging that would result in soil compaction,

--scheduling thinnings when vectors are least active, and

--minimizing injury to trees when thinning and road building.

(5) Brown Cubical Root Rot

Major Host: Douglas-fir

Other Hosts: Several other conifers.

Geographic Area: Brown cubical butt rot is found throughout the West Coast and Northern Rocky Mountain areas.

Status: The disease is the cause of butt rot of Douglas-fir and, if fire scarred, of other conifers. Damage has been extensive in old-growth stands. Root-rotted trees are susceptible to bark beetle attack and windthrow. The disease sometimes kills young or stressed trees. But much less damage is expected in young-growth managed stands than in old-growth.

Causes: *Phaeolus* (*Polyporus*) *schweinitzii* is the cause of brown cubical butt rot. Fire has been a contributor to damage by injuring trees and creating fire scars.

Control: Damage can be minimized in young-growth stands by regenerating with site-suited species, regulating stocking density, avoiding wounds when thinning, and reducing rotation lengths.

ROOT DISEASE IMPACTS: Root diseases are affecting about 9.6 million acres of commercial forest lands of all ownerships in the west (Table 2). This represents about 6-1/2 percent of the commercial forest land.

Area affected is an estimate of the forested area in each western State where root diseases are killing trees. It includes area occupied by root disease centers where the land is out of timber production, areas where root diseases are killing only individual scattered trees, and combinations of the two. It does not include potential problem areas, i.e., acres that are infested by root pathogens but where the major hosts are now absent, acres where hosts are present and pathogens are likely to spread, or acres on which damage other than tree mortality occurs. Estimates for individual States were provided by the respective Regions. They are best estimates based in a few cases on considerable data and in others on very little.

Table 2.--Acres of commercial forest land on all ownerships where root diseases are killing trees, average annual root disease-related mortality, and stumpage value of the mortality.*

	Acres affected	Annual mortality (M cu ft)	Stumpage value ($)
Pacific States			
Alaska	24,000	**	**
California	2,005,000	19,300	10,129,725
Hawaii	700	--	--
Oregon	1,650,000	100,000	45,000,000
Washington	1,350,000	84,000	37,600,000
Rocky Mountain States			
Arizona	281,600	2,107	200,165
Colorado	38,400***	137***	22,225***
Idaho	1,929,000	41,210	7,211,750
Montana	1,400,000	40,000	7,000,000
Nevada	500	25	5,000
New Mexico	858,700	2,653	252,035
Utah	50,000	950	166,250
Wyoming	5,500	105	18,375
Total	9,593,400	290,477	107,605,525

*Modified and expanded from table 2, P. 81, Insect and Disease Conditions in the United States - 1979-83, GTR WO-46.

**Indicates no information available.

***Area and volume for subalpine fir in spruce/fir type only.

The average annual volume of tree mortality is estimated at 290 million cubic feet (table 2), or about 1.5 billion board feet . This estimate, like that for acres affected, is based on some survey data and considerable extrapolation. It is considered a conservative estimate of timber volume loss from root disease because it does not include estimates from growth loss or butt rot. It also does not include production foregone in understocked disease centers. The stumpage value of 290 million cubic feet amounts to about $108 million. The estimates for volume killed and value of the timber are average annual volumes. Little information is available on how losses fluctuate by year. The loss estimates are probably representative of the past 10 years, at least.

Root diseases affect resources other than timber. Two important effects of root disease are on recreation values and fire potential. Root diseases alter the use of recreation areas. They also make trees susceptible to windthrow, creating a hazard to people and property. Root diseases have greatly increased fire hazard in some stands as slash accumulates from tree mortality and wind-thrown trees, and regeneration creates a fire ladder to the crowns. Losses to values other than timber have not been quantified.

<u>CONTROL RESPONSES</u>: Technology does not exist to control root disease outbreaks directly, in the sense that insect outbreaks may be controlled. Consequently, little has been done in terms of <u>direct</u> control of root diseases.

Actions could have been taken to reduce the damage from current outbreaks if the root disease problem had been anticipated. The actions would have been the silvicultural practices described in other sections that reduce stand vulnerability (favor disease-tolerant tree species) and reduce inoculum buildup (reduce the number of stand entries, especially by limiting sanitation cutting). Unfortunately, the root disease problem has been recognized only for the past 2 decades and still has not been adequately assessed. Current outbreaks are in part the product of management actions that have inadvertently favored root pathogens. These actions include the following:

> Fire control and partial cutting favored Douglas-fir and true firs on many habitats where these species are climax, but historically were prevented from reaching the climax condition through repeated, low intensity ground fires.
>
> Selective logging of cedar, ponderosa pine, western larch, western white pine, and other valuable species also favored the more disease-susceptible Douglas-fir and true firs on many sites.
>
> Planting pure stands of susceptible species (usually Douglas-fir) and off-site plantings of less susceptible trees created especially susceptible stands.
>
> Harvesting and site preparation methods reduced site productivity.
>
> Overstory removals from infected Douglas-fir/true fir understories were made rather than regenerating to less susceptible species.
>
> And tree harvest provided both food bases for the pathogens and loci for new diease centers in the case of annosus root disease.

Forest management actions to reverse these past trends can do much to prevent future outbreaks. Procedures are available to reduce spread of annosus and black stain root diseases. Losses can be reduced in some currently infected stands by limiting stand entries and early regeneration cutting. But, given current technology, the course of the current outbreak will be changed only by decades of appropriate silvicultural treatment.

TREATMENT OPTIONS: Root diseases limit management options. They limit the number of entries that can be made, limit the species options, limit rotation lengths, and in other ways reduce a manager's options.

Nevertheless, many sites can be restored to nearly full productivity by appropriate modifications in silvicultural treatments. In general, the appropriate treatments are aimed at establishing and maintaining site-suited stands of the most disease-tolerant species.

Silvicultural control: It is difficult to estimate how well root disease recommendations are actually carried out. Root disease management is done at the stand level by local managers, often without the knowledge ofpathologists. Some practices that reduce root disease losses are just good forestry--conservation of topsoil and organic matter, for example. Others, like the regeneration of Douglas-fir and true fir climax types with seral species, are done both for disease reduction and other reasons. Nevertheless, some treatments are prescribed specifically for root disease control, especially in California, Oregon, Washington, Idaho, and Montana, where disease losses have been best documented. Some of these are costly.

Root diseases increase costs of forest management in a number of ways:

--Some diseased areas are planted that otherwise would be regenerated naturally. This is costly. As an example, in the Idaho Panhandle National Forests, it has been estimated that about one-third of the acres regenerated each year are either planted or interplanted because of the need for disease-tolerant species on the site. Natural regeneration would have been acceptable otherwise. Perhaps 10 percent of the acres regenerated on other R-1 Forests with root disease problems are planted because of root disease. At a cost of $260/acre for planting or $175/acre for interplanting, the annual expenditure is $1.2 million.

--Special treatment of root-diseased areas during planting and precommercial thinning adds costs to those operations. R-6 foresters estimate this adds about 10 percent to planting and thinning costs in diseased areas, or about $170,000 per year.

--The cost of stand exams is increased because of the need to examine trees for disease.

--Additional time is needed to evaluate disease and modify stand prescriptions.

--The need to keep track of diseased stands and parts of stands complicates stand recordkeeping.

--Some severely affected stands require stand destruction, site

preparation, and planting. Little of this has been done to date, but a sizable backlog of such stands exists. This is a costly operation.

Stumping: The extraction of stumps from the soil following harvest removes inoculum of root pathogens. It is not widely practiced. In most States, the practice is confined to special use areas such as seed orchard and test plantation sites. Perhaps several hundred acres are stumped in the West each year--1,000 acres at most. Stumping costs are in the hundreds of dollars per acre.

Borax treatment of stumps: Borax stump treatment for annosus root disease prevention is carried out operationally in recreation and other high use areas in the Pacific Coast States. The practice is also operational in east side pine timber sales in California and some true fir sales in Oregon. It is used occasionally elsewhere. Perhaps 1,000-2,000 acres are treated each year in the West at a cost of $15,000-$30,000. Cost of the material and application is about $1 per stump.

Hazard tree removal: The removal of root-rotted trees from campgrounds and other high use areas reduces hazards to people and property. Annual tree inspections, recordkeeping on tree condition, and removal of hazardous trees is practiced to some degree in all western States. No estimate of the cost of these practices is available, but the cost is considerable. An economic evaluation made in Yosemite Valley, for example, suggested that the cost of annosus root disease-caused hazard tree management in that National Park would be $42,300.

Treatment summary: It would be reasonable to assume from the foregoing discussion that the annual cost of treating root diseases on public lands alone is in excess of $1.5 million. Yet, only a few tens of thousands of acres are treated each year of the millions of acres that are infested (less than 1 percent). Treatment is appropriate only on a fraction of the infested land. But there may be opportunities to increase the area treated several fold. The opportunities include shifting timber harvest to high risk stands, reducing rotation length, increasing planting, and regenerating the backlog of infested land that is out of production.

TECHNOLOGY INFORMATION: There is widespread concensus among pathologists on the applicability of silvicultural manipulations to prevent and reduce root disease losses. But, much of the technology is based more on experience and observations than on data. The major approach is to favor disease-tolerant species. Yet, few data are available on the performance of many conifers on diseased sites. Furthermore, no feasible controls are available for a substantial acreage of infested lands because resistant species are not suited to the site or because treatments are uneconomical.

There are also many unanswered questions regarding the behavior of root pathogens and the effect of silvicultural practices. At best, large losses will be suffered in existing stands over the next several decades until treatments can be scheduled and carried out on the many thousands of infected acres. The need for new technology is urgent.

The following list is a general summary of the new technology needs. More detailed and complete lists are available elsewhere, especially in the reports from the *Armillaria* and *Phellinus* modeling workshops.

-Species tolerant to root diseae and intraspecies variation needs further study.

-The beneficial and detrimental effects of various silvicultural activities on *Phellinus* and *Armillaria* need to be identified and measured. We need to reliably plant and culture serial (root disease tolerant) species in affected areas. The effects of various regeneration methods and effects of precommercial thinning are also crucial.

-A better understanding of root disease stand dynamics is needed. What factors trigger outbreaks? How is scattered tree killing related to centers?

-The root disease stand prognosis model that has been developed for *Phellinus* and *Armillaria* root diseases needs to be tested, validated, and refined. Models need to be developed for other root pathogens in other areas.

-Stand risk and hazard rating techniques are needed to predict root disease incidence and effects, especially in the absence of obvious damage in the present stand.

-Information is needed on the efficacy of borax for preventing *H. annosus* infection, especially for true fir stumps.

-More information is needed on the effect of root disease on tree growth, especially under conditions where tree killing is not a major effect.

ADDITIONAL DISCUSSION:

1. Obstacles to the use of existing technology include the following:

--Probably the greatest obstacle is lack of convincing data on root disease effects. Some Regions have not yet determined where root disease losses are occurring and what pathogens are responsible for the problems. None have adequate data on the extent of the damage (acreage affected). And we are just beginning studies to measure losses in timber productivity for individual stands.

--Regneration to less susceptible species is sometimes not accomplished because of difficulty in identifying hazardous sites, especially in the absence of damage; the lack of recognition of root disease problems by stand exam crews and foresters preparing prescriptions; the lack of suitable disease-tolerant species for the site; and short-term economics (natural regeneration is cheaper).

--Stump removal is not widely practiced because of questions regarding its effectiveness, cost effectiveness, and effect on soils. It is also not practical on steep slopes.

--Borax stump treatment would be more widely used for annosus root disease prevention if the sites where treatment is necessary could be identified. We need to be able to predict where the pathogen will and will not affect stumps, and where the stump infection will result in economic loss.

--Root disease-caused hazard trees are sometimes not removed because inspectors have not had proper training in root disease recognition, and because adequate funding is not available for tree inspection and removal.

Treatments to reduce root disease-caused timber losses are not prescribed because of conflicts with other forest uses and values. Hydrologic constraints prevent the treatment of all infested stands in a drainage needing treatment. Some diseased stands are left for wildlife cover. And others are not clearcut because of visual constraints.

2. The greatest limitation to effective response to the root disease problem is inadequate funding for research and action programs. Probably more FPM work-year equivalents are devoted to root diseases than any other western disease group. Yet, this effort does not adequately address training and technical assistance needs. Impact evaluation has been seriously neglected, especially in recent years.

3. Perceived issues:

a. Only one of the major root pathogens, Phaeolus schweinitzii, increases in importance as forests exceed rotation length. The remaining four are damaging in younger stands and intensified by forest management practices.

b. Forest Plans and the National Forest planning process do not adequately address root disease effects. They are commonly included in a category called "insects and diseases" that will be managed with "integrated pest management techniques." Only one National Forest, the Suislaw, reduced projected yields because of root disease. The major reason for the abbreviated treatment was the inability to predict the effects of root disease on timber productivity, either with data or with models.

Several of the Forest Plans did identify the need for root disease research. For example, the three most important timber-producing Forests in R-1 addressed the need. This resulted in the following Regional research priority: "Identify hazard rating systems and management techniques and strategies to reduce losses from root diseases."

c. The decision to take action against root disease is usually made on a stand-by-stand basis at the local level. For a silvicultural prescription to be altered (a regeneration cut, for example) the following steps must be completed for the specific stand in question:

--Determine from stand data that root disease may interfere with management objectives.

--Identify disease treatment options.

--Consider the environmental and social consequences.

--Weigh the costs and benefits of treatments.

--Select and implement an alternative.

Although detailed analyses are not always made (or needed), the general process is thought through and results are documented in silvicultural prescriptions.

Some control decisions have been made at the Forest or Regional level. Examples of this are the R-5 and R-6 regional policies to treat all stumps in recreation areas with borax. The Modoc and Lassen National Forests have similar policies for treating stumps in east side timber sales.

d. A segment of the public places high priority on forest visual quality. Specifically, clearcutting is found objectionable. The regneration cut is a critical step in root disease management. It can set the stage for either large or negligible losses in future rotations. Loss prevention and reduction techniques necessitate regeneration with disease-tolerant species. This usually means clearcutting. The public does not fully understand these trade-offs between timber production and short-term visual degradation.

e. The need for new technology for root disease management is urgent.

f. Root disease damage has increased as a direct result of fire control, partial cutting, monoculture, continuous cropping, off-site planting, soil degradation, and other man-caused changes. The actions have been discussed throughout the report.

g, h. The public perception of pests and pest-caused damage and public involvement have affected forest health in a number of ways. On the positive side, public concern has helped maintain research and action budgets. On the negative side, misconceptions may have resulted in less than optimal use of available funds:

--The failure to recognize the importance of insidious pests like root pathogens has meant that research and action programs have often focused on more spectacular but less damaging pests.

--The public's view of pest management has resulted in the demand for suppression attempts at the expense of prevention. The imbalance between FPM survey and technical assistance budgets on the one hand (largely prevention) and suppression budgets is one manifestation of this.

--The public's perception of acid rain as the primary cause of forest declines has narrowed the scope of investigation on and to declines and has diverted funding from other important research needs.

i. The frequency and intensity of root disease varies by land ownership. For example, some National Forests and some private companies regenerate stands primarily by clearcutting and planting or by seed tree cutting. Others partially cut most stands. Some agencies treat stumps with borax; others

don't. But it would be hard to generalize about differences in root disease by ownership.

RECOMMENDATIONS: This section contains my personal view.

It is apparent that root diseases rank high in the list of pests that affect timber growth and yield, at least in the Pacific Coast States, Idaho, and Montana. Of all the insects and diseases, root diseases offer the greatest potential for damage in the young growth stands from which we expect to supply timber in the next century. Root diseases merit more attention both from Forest Pest Management and Forest Insect & Disease Research than they have received in the past.

Many aspects of the problem need attention. Some that I consider most important are discussed below. These needs cannot be addressed with existing resources. In FPM, for example, we are already devoting as much of our current resources to root diseases as we can. Reduced pathology staffing in recentyears in some Regions has resulted in reduced emphasis upon both root diseases and other economic diseases.

--FPM needs to better inform managers and the public of the problem. Much progress has been made in recent years by training silviculturists and foresters to recognize and manage root disease. But neither they nor we pathologists have done an adequate job of informing District Rangers, Forest Supervisors, Regional Foresters, Station Directors, and elected officials of the root disease problem.

--Additional impact data is needed. In Regions 1, 5, and 6, information is needed on the effects of root disease on stand growth and yield. We already know a major root disease problem exists in these Regions. In other Regions, much work is yet needed to define the magnitude of the problem, even to determine whether a problem exists.

--The recent attention given to root disease by research should be encouraged. The development of *Phellinus* and *Armillaria* extensions to the PROGNOSIS model has been a major accomplishment. Other research is also needed. This research should be applied research on ecology and silvicultural management of the diseases and can be done best "in house." A sustained effort is needed, one that builds on new knowledge.

--A sustained effort is needed to prepare to model root disease effects for the next round of Forest Plans. This will require testing and refining existing models as well as adapting the models to other pathogens and Regions.

--Finally, I think both FPM and FIDR might consider some new approaches to obtaining information on pest management. One such approach is the application of statistical methods developed for medical research to pest population data. Enough of this work has been done by the biometrics group at MAG to demonstrate its potential. Considerable underutilized data on pests and stands are available from surveys and evaluations done by FPM and the Forests (stand exams, permanent growth and yield plots, pest surveys, aerial surveys, etc.).

Analysis of such data could identify what type of stands and trees are at risk from root disease, associations between root disease and other pests, and other valuable information--much like human population data has been used to identify traits in people that are associated with cancer or heart disease. Such information would find immediate application on the Districts, and would provide Research with suggestions for fruitful lines of reseach on causal relationships.

[illegible]
Task Force [illegible] Diseases, [illegible]
other pests, and other valuable information [illegible]
[illegible]
associated with [illegible] diseases
[illegible]

[illegible]

[illegible]

WESTERN SPRUCE BUDWORM

Dayle D. Bennett

Major Pest: Western Spruce Budworm (WSB)

Ecosystems and geographic "area covered" in this analysis: Geographic area includes most of the mixed conifer and spruce/fir forests of the Rocky Mountains from Arizona and New Mexico northward into Colorado, Utah, Wyoming, Montana and Idaho; and in the Pacific Northwest in Oregon and Washington. In the northern Rocky Mountains, the Okanogan highlands of north central Washington, and in the Blue Mountains of northeastern Oregon, WSB infests most habitat types in the following series: Douglas-fir, spruce, grand fir, western red cedar, western hemlock, and the lower subalpine fir subseries (USDA Tech. Bull. No. 1695). In the central and southern Rocky Mountains, WSB occurs throughout the Douglas-fir, white fir, spruce, and subalpine fir series.

Background

Distribution: WSB is widely distributed throughout coniferous forests of the western United States.

Description of preferred host(s): Preferred hosts include Douglas-fir, grand fir, white fir, Engelmann spruce, and western larch.

Interior Douglas-fir grows in pure or nearly pure stands in parts of eastern Washington and Oregon, and in the northern and central Rocky Mountains. Elsewhere it grows in association with other coniferous tree species. Its shade tolerance is intermediate. Successionally, it occurs as both climax and seral. Coastal Douglas-fir occurs in pure stands over extensive areas on the west side of the Cascade Range in Washington and Oregon, and in stands mixed with grand fir and white fir in southern Oregon. Shade tolerance of coastal Douglas-fir is lower than most of its associates and it is usually seral except on extremely dry sites. Douglas-firs are valuable timber species throughout most of their range.

Grand fir occurs in pure stands in central Idaho, and in mixed species stands throughout the rest of its range. It is relatively shade tolerant and often occurs as an intermediate or in the understory. Successionally it ranges from seral in its high, cool and moist Pacific Coast range to climax on the low, or warmer, drier regions of its interior range.

White fir is a shade tolerant to very shade tolerant climax species which usually occurs in mixed species stands in Oregon and the Rocky Mountains.

Engelmann spruce and subalpine fir occur in both pure and mixed species stands. They are very shade tolerant species and, depending upon their location, considered either subclimax or climax.

Western larch rarely grows in pure stands. It is commonly associated with Douglas-fir, grand fir or ponderosa pine. It is a shade intolerant, seral species that is favored by wildfire (USDA Tech. Bull No. 1694).

Area occupied by host vegetation (acres and acres by ownership): Host vegetation (M acres by ownership derived from RPA data base).

*Suggest these figure be extracted from WO RPA data base!

	NFS	Other Public	Industrial Private	Non-Industrial Private	*Mixed Reserve	Total
R-1	6,508.0	1,196.0	805.0	2,160.0	0	10,669.0
R-2	4,628.6	390.0	8.5	805.5	3,724.2	9,556.8
R-3	1,338.4	546.2	1.2	593.5	3,029.2	5,508.5
R-4	5,287.0	2,023.8	754.2	1,415.4	-	9,480.4
R-6	3,595.0	1,398.8	1,398.8	-	-	6,392.6
Total	21,357.0	5,554.8	2,967.7	4,974.4	6,753.4	41,607.3

*Mixed species and mixed ownership.

Outbreak cycles and triggers: WSB outbreaks follow no apparent pattern or trend. Most of the early recorded outbreaks lasted for only a few years, then subsided naturally. Others have persisted for over 30 years in spite of repeated suppression attempts through insecticidal treatments (Fellin and Dewey--FIDL 53). This wide variability in outbreak frequency and duration suggests WSB populations may be responding to a similar physiological stress in host trees (WSB Tech. Bull. 1694).

The dynamics of localized WSB outbreaks and subsequent damage to host trees are strongly related to forest conditions and site characteristics. Susceptibility to infestations and vulnerability to damage are closely aligned. Stand susceptibility and vulnerability are affected by intrinsic stand characteristics, such as host phenology, species composition, density, structure, vigor, maturity, acreage of contiguous host type, and proximity to current outbreaks. Those stands most susceptible are dense, mature stands composed of shade-tolerant host species on xeric sites. In general, stand susceptibility increases as forest succession advances and net production of the stand decreases. Climate and topographic conditions interact with stand conditions to modify susceptibility and perhaps trigger the onset of outbreaks.

Attack behavior/damages: WSB larvae feed on buds, foliage, seeds, and cones of host trees. Several consecutive years of feeding can result in heavy crown defoliation, height-growth loss, radial growth loss, reduced cone and seed production, and some tree mortality. In addition, stand structure, composition, volume recovery, and regeneration are altered by WSB outbreaks. Other impacted resources include visual quality, recreation, and wildlife.

Defoliation and discoloration are the most obvious effects of WSB feeding. Sustained, heavy outbreaks may cause nearly complete defoliation in 4-5 years in the overstory, earlier in the understory (USDA Tech. Bull. No. 1695).

Height growth is affected in at least three ways: 1) Growth may be reduced during light defoliation periods; 2) an annual internode is not produced if the terminal bud is mined or destroyed; or, 3) internodes can be top-killed during consecutive severe defoliations (USDA Tech. Bull. No. 1695). During a 5 year study in Idaho, 12.7 percent of young defoliated trees showed no height growth. Studies in Region 3 have shown highly variable incidence of top-killing within the WSB outbreak of northern New Mexico. In 1980, 4.3 percent of the sawtimber trees, 7.3 percent of the poles, 10.3 percent of the saplings, and 12.3 percent of the seedlings examined in a long-range damage assessment project showed some degree of confirmed top-kill. By 1983 top-killing in these same areas had increased to 29.1 percent in the poles and 16.8 percent in the sawtimber; seedlings and saplings were not sampled in 1983.

Defoliation by WSB has been shown in several studies to markedly reduce radial growth. Annual increments of Douglas-fir were reduced during early infestations by 12 percent in diameter and 22 percent in basal-area compared to average potential growth. A study in Region 3 (Swetnam, 1983) revealed radial growth loss was observable during three of the past WSB infestations on the Carson NF: Maximum growth loss during a single year of the outbreaks was usually greater than 50 percent, while average growth loss during five year periods was approximately 30 to 40 percent.

Reductions in both radial growth and height growth equate to reduced volume, however few WSB-caused volume loss studies have been conducted. Region 1 estimates an average volume loss of 7 cubic feet per acre per year on 31.5 board feet per acre per year within WSB infested areas. In eastern Washington, stand volume loss averaged 5.9 percent of the predicted growth over a 10-year period. In central Idaho, volume loss in individual trees ranged from 0 to 93.3 percent.

Seed and cone loss may reach 100 percent in severe outbreaks and the ability of surviving trees to produce seed may be compromised for several years following an outbreak. Even when foliage feeding was light, 9 to 71 percent of the Douglas-fir cones were infested in 13 stands in Montana. Many of the small conelets shriveled and died.

WSB-caused tree mortality, even after several years of defoliation, is usually light and generally restricted to smaller, suppressed trees. Overall mortality during an outbreak is less than 10 percent, but may be as high as 50% in individual stands. Additional tree mortality may occur during or shortly after an outbreak as trees severely stressed from repeated defoliation are predisposed to attack by bark beetles.

Current situation (as of 6/30/87): Presented by Region

Region 1

INFESTED HOST ACRES BY OWNERSHIP

FOREST ZONE	NFS	OTHER PUBLIC	INDUSTRIAL FOREST	OTHER PRIVATE
North ID.	5,670			
Mont.	1,217,565	254,070	206,545	826,180
Total	1,223,235	254,070	206,545	826,180

PERCENT

Host Occupied	18.8	21.24	25.66	38.25

Course of outbreak: WSB outbreaks are more persistent east of the divide than in western Montana and northern Idaho. In northern Idaho and western Montana the outbreaks last about 10 years with a 10-15 year period between outbreaks. In eastern Montana the cycle is about 10 years with a 5-10 year period between cycles. There are places where outbreaks seem to be more persistent than others.

When did outbreaks start? First reported outbreak was in 1922 at Priest Lake, Idaho.

Where did each start? NA

What are the expectations for future outbreaks? Outbreaks will continue until timber management activities or fire management has changed the forest conditions. This of course will not occur because many areas will not be managed for timber, and it is unlikely fires will be used to reduce host forest where no timber management is planned.

What caused this outbreak? See "outbreak cycles and triggers."

Describe current control program: Current control program consists of silvicultural practices of changing the forest conditions to reduce the impact of the spruce budworm. We have also used B.t. in a very limited area to secure regeneration in areas where timber harvest is in progress.

Silvicultural control is accomplished on 3,960 acres of Forest Service lands, annually. Cost of treatment...None to FPM.

Impacts: Acres affected all ownerships all land classes...2,510,030 acres.
Physical loss: 7 cubic feet/acre/year or 31.5 BF per acre per year.
Volume loss: = 1,255,015 suitable acres x 31.5 BF/acre/year = 39.5 MMBF
Use loss: Big game hiding cover = 2,510,030 acres x .0117 days per acre per year = 29,362 recreational visitor days lost per year.
Monetary: Timber loss = 2,510,030 acres - 1,255,015 suitable acres = year x $40 per M = $1,581,320 per year.

Recreation day loss: = 29,362 days per year x $25.75 per day = $750,072 per year.
Total annual loss: = $1,581,320 + $750,072 = $2,331,392 per year in Montana and northern Idaho.

Control responses:

What control was taken on these outbreaks? In the early 50s direct control with aerial spraying was undertaken. This ended in 1966. Since then no large spray programs have been done.

What control could have been taken? It could have continued.

What could have happened with no control? Stand volumes would be less.

What could have been done to prevent the outbreak? Fires could have been left to burn and reduce host acres. Cutting practices of removing ponderosa pine and the absence of fire has created more acreage of high hazard stands.

Region 2

For this review, we are considering the Region as having one outbreak, even though it is broken into three major areas at present: southwest Colorado, Front Range of Colorado, and the Clarks' Fork District of the Shoshone National Forest. We believe that these significant oubreaks were released through climatic conditions suitable for the insect, though no definitive work has been done to support that in this Region. Smaller outbreaks can be found almost every year in some area of the Region. These are usually associated with Douglas-fir or white fir growing on poor sites. Several areas along the Front Range of Colorado have supported a visible population each year since the early sixties when aerial surveys were begun.

The present outbreak went through its release phase in 1974 or '75. Visible defoliation peaked in 1983 at 2.7 million acres. By 1986, visible defoliation had decreased to 1.1 million acres which is still ten times the level of defoliation experienced in the 1960's. Visible defoliation in 1987 is expected to be about the same as in 1986. At the peak of the present outbreak nearly all the Douglas-fir and true fir habitat type was infested. Subalpine fir and spruce growing adjacent to these areas were also subjected to heavy defoliation. Considering the fact that only 1.3 percent of the Douglas-fir cover type has been regenerated per decade over the past 80 years and that nearly 5 percent of this type is over 200 years, and that most of this 5 percent is in uneven-aged stands the prognosis for a decline in long-term budworm activity is not good. We expect the present outbreak to decline substantially over the next few years. Regeneration of the host type into a better stocking condition is pre-empted by poor markets and steep slopes. Only about 3.4 million board feet is harvested in the Douglas-fir type annually.

In 1982, an Environmental Analysis was prepared covering the outbreak. The decision reached in that EA was to protect recreation sites through pesticide application if needed and to allow the outbreak to follow its natural course on remaining lands. The only exception was where private

landowners, at their cost, decided to spray National Forest lands immediately adjacent to spray projects on private land could do so on a case by case basis. It was felt that the losses of esthetic and timber values were acceptable based on public opinion, economic evaluation and current policies and objectives on National Forest lands. During this outbreak, private landowners have sprayed 10-20,000 acres annually, primarily along the Front Range. No cost estimates are available on expenditures, but treatment costs are known to have varied between $14 & $20 per acre. Treatment blocks have ranged from less than 20 acres to several hundred acres. No projects have been initiated on Federal lands by Federal agencies during this time.

Impacts: An analysis of the impacts of this outbreak has not been attempted since it continues. The economic analysis done with the EA shows that a net loss of $93,685 would occur under the assumptions utilized. Since tree mortality has been greater than expected, as well as being compounded by the interjection of Douglas-fir beetle, the loss may be two to three times greater than anticipated. We wouldn't expect the loss to be higher since most of the volume is inaccessible, and is further offset by increases in wildlife habitat and water yield. Had the decision been made to aerially spray the outbreak in 1982, the net present value would have been a negative $15-30 million. Under the silvicultural emphasis alternative, the net loss would have been -$67,000. However, markets and other constraints would most likely have prevented this from happening since the success of this alternative was based on a strong fuelwood demand, which has since peaked.

Control responses: Suppression projects could have been initiated in 1975 or 1976 when the acres infested first started to expand. At that time a large scale mountain pine beetle control project was the first priority, with considerable public support. Public concern was not high until 1980 when we predicted that over a million acres would become infested. We were faced with hard choices between funding MPB suppression projects or overcoming a strong public negative attitude toward aerial spraying of insects. Analysis of the total pest picture continued to support greater emphasis toward the bark beetle situation. Our analysis in 1982 further verified that the expenditure of a large sum of money to control the outbreak was not in the best public interest. Analysis of the present situation continues to support the decisions made regarding this outbreak. While many acres show a significant amount of top kill, underneath is a new stand of trees with greater species diversity than the previous stand. In these areas of inaccesibility, nature has done what the forester would like to see, regeneration of a new healthy forest.

Less than 2 percent of the Regions' annual harvest comes from the Douglas-fir/true fir type. Future outbreaks will not be prevented. However, as demand for all products increases from these cover types an effort will be made to create stands that support less budworm. Such efforts are underway now where access to the cover types is available. For many acres though, we do not see stands being actively managed for some time. Once the present outbreak collaspes back to what we consider to be loci for the budworm, we intend to manipulate those areas to reduce "prime budworm habitat." Costs and extent of this activity are unknown at this time.

Region 3

Three separate outbreaks are currently in progress within Region 3. They are: 1) The northern Arizona outbreak; 2) the east central Arizona outbreak; and 3) the northern New Mexico outbreak. A fourth outbreak, the Lincoln NF/Mescalero Apache IR outbreak was treated in 1984 and has since been at low levels.

Status of outbreaks:

1 - Northern Arizona - Static
2 - East Central Arizona - Static
3 - Northern New Mexico - Static
4 - Lincoln/Mescalero - Collapsed

Percent of host habitat occupied:

1 - Northern Arizona - Varies from 25 to 80 percent.
2 - East Central Arizona - Less than 1 percent.
3 - Northern New Mexico - Varies from 25 to 80 percent.
4 - Lincoln/Mescalero - Less than 1 percent.

Acres occupied in 1986:

1 - Northern Arizona - 83,120
2 - East Central Arizona - 7,500
3 - Northern New Mexico - 371,600
4 - Lincoln/Mescalero - 7,200

Course of the outbreaks: The northern Arizona and the northern New Mexico outbreaks began in the mid 1970s and have fluctuated annually in intensity and area. Because highly susceptible stand conditions exist over thousands of contiguous acres in these areas, both outbreaks are expected to continue, with similar area and intensity fluctuations, for an indefinite period of time.

Defoliation in the east central Arizona outbreak was first detected in 1985 on 9,000 acres of the Gila and Apache-Sitgreaves NFs. Area of defoliation remained about the same in 1986 and is expected to continue in 1987. Based on historical records and stand susceptibilities, this outbreak is not expected to last long, nor result in significant damages.

The Lincoln/Mescalero outbreak was first detected in 1981 on 625 acres. Defoliation increased to 6,625 acres in 1982 and 108,000 acres in 1983. This outbreak was aerially treated with pesticides (carbaryl and B.t.) in 1985--241,000 acres--, and WSB populations have remained at very low levels in the treated areas since. These low levels are expected to continue, however, future outbreaks are inevitable as long as susceptible stand conditions exist.

Cause of outbreak: The underlying cause of all outbreaks in R-3, and the rest of the western U.S. is the susceptibility of stands within the host type, i.e., unevenaged, dense, mature stands composed of shade-tolerant

host species on xeric sites resulting in reduced tree and stand vigor (USDA Tech. Bull. No. 1694). The release phase of these outbreaks may have been triggered by general climatic conditions which further stressed trees, reduced their defensive chemistry, and favored WSB development and survival.

Describe the current control programs:

1 - Northern Arizona - Based on the final environmental impact statement for WSB issued in 1981, WSB is being managed through silvicultural manipulation to reduce stand susceptibility on National Forest lands. Number of acres treated and costs per year are unknown. No action is the adopted course of management on National Park lands.

2 - East Central Arizona - No control has been initiated and none is anticipated for this outbreak.

3 - Northern New Mexico

Year of Treatment	Type of Treatment	Acres Treated	Percent of Infested Area Treated	Cost Per Year
1977	Aerial Application of Pesticide (Pilot Program)	37,450	<5	$319,387
1981	Aerial Application of Pesticide (B.t. Pilot Program)	15,700	6	260,000
1982	Aerial Application of Pesticide	71,000	22	636,500
1983	Aerial Application of Pesticide	33,500	14	271,341
1984	Aerial Application of Pesticide	34,537	6	245,855
1985	Aerial Application of Pesticide	23,320	5	235,227
	Ground Application of Pesticide	33	<1	37,000
1986	Aerial Application of Pesticide	2,800	<1	34,000
	Ground Application of Pesticide	15	<1	17,000

4 - Lincoln/Mescalero

Year of Treatment	Type of Treatment	Acres Treated	Percent of Infested Area Treated	Cost Per Year
1984	Aerial Application of Pesticide	240,900	95	1,413,536

Impacts:

1 - Northern Arizona - A sample of four heavily defoliated areas, totaling 26 acres, in 1980 showed top-kill ranged from 25 to 46 percent, and several dead trees, "presumably killed from repeated budworm defoliation," were noted (EIS, WSB Mgmt. Kaibab NF and Grand Canyon NP, 1981). Defoliation on up to 83,000 acres is the only impact documented in this outbreak since 1980.

2 - East Central Arizona - Impacts, thus far, are minimal and limited to visual impacts of defoliation.

3 - Northern New Mexico - Documented impacts include:

a. Annual defoliation on up to 500,000 acres.

b. An impact survey on the Carson NF in 1984 showed mortality due to repeated WSB defoliation averaged 8 percent in the understory and 4 percent in the overstory over a 9,000 acre area and 4 percent in the understory to 19 percent in the overstory over a 300 acre area. Extensive top-kill was noted throughout the 9,300 acres, but no data were collected.

c. An impact survey on the Santa Fe NF in 1983 (Cecilia Timber Sale) showed top-kill ranged from 0 to 63 percent in trees over 12" dbh, 0 to 67 percent in trees 9-11.9" dbh, 0 to 84 percent in trees 5-8.9" dbh, and 3 to 75 percent in trees under 5.0" dbh. Mortality over the same 3,200 acre area ranged from 0 to 15 percent in the trees over 12" dbh, 0 to 33 percent in the trees 9-11.9" dbh, 0 to 60 percent in trees 5 to 8.9" dbh and 0 to 52 percent in trees under 5.0" dbh.

d. A long range damage assessment survey on the Carson NF showed top-killing of 12.3 percent of the seedlings, 10.3 percent of the saplings, 29.1 percent in the poles and 16.8 percent in the sawtimber.

No other impacts have been documented.

4 - Lincoln/Mescalero - No lasting impacts were documented following the decline of this outbreak.

Control Responses:

What controls were taken? See previous section describing current control programs.

What controls could have been taken?

a. Northern Arizona - Alternatives considered for this outbreak included: 1) No action; 2) silvicultural control to reduce susceptibility and vulnerability of stands on the Kaibab NF; 3) Integrated Pest Management...aerial application of a pesticide on both Kaibab NF and Grand Canyon NP; and 4) partial treatment of selected high value areas or National Forest lands only.

b. East Central Arizona - No analysis of this outbreak has been conducted. Generally, controls that could have been taken include silvicultural manipulation of susceptible stands and pesticide application to reduce WSB populations.

c. Northern New Mexico - More area could have been treated with pesticides.

d. Lincoln/Mescalero - This outbreak was controlled.

What if no control had been attempted?

In the northern Arizona and east central Arizona outbreaks, and portions of the northern New Mexico outbreak, no control has been taken and the outbreaks continue to run their course, resulting in annual fluctuations of defoliation and resultant impacts to a variety of forest resources. If no control had been taken on the Lincoln/Mescalero outbreak it would probably have continued to cause defoliation and resultant impacts for an indefinite number of years.

What could have been done to preclude this outbreak? The only effective means of preventing these and future WSB outbreaks is through silvicultural manipulation to reduce stand susceptibility.

Region 4

Information pertaining to the current western spruce budworm outbreaks in the National Forests in Region 4.

State	NF	Host Type (AC)[a]	Outbreak Origin Site	Outbreak Origin Year	1986 Defol. (AC)[a]	Status[b]
Idaho						
	Boise	1,109,000	West Mtn.	1973	1,134,000	decreasing
	Caribou	227,000	McCoy Cr. Jacknife Cr.	1981	277,000	decreasing
	Challis	434,000	-	-	35,000	decreasing
	Payette	1,082,000	West Mtn.	1968	618,000	decreasing
	Salmon	491,000	-	-	30,000	decreasing
	Sawtooth	320,000	Big & Little Smokey Creeks	1981	355,000	decreasing
	Targhee	427,000	Dubois RD	1977	457,000	decreasing
Utah						
	Dixie	238,000	-	-	27,000	decreasing
	Fishlake	153,000	-	-	5,000	decreasing
	Wasatch-Cache	164,000	Logan Canyon	1984	63,000	decreasing
Wyoming						
	Bridger-Teton	642,000	Snake River Willow Cr.	1974	112,000	decreasing

[a] Host type acreage figures were compiled from the RPA Region 4 database. Defoliation acreages compiled from the 1986 aerial survey may exceed total acreages of host type because small blocks of state and private ownerships and mixed stands may be interspersed within the forest boundary.

[b] Status refers to the qualitative trend in defoliation levels detected by aerial survey. Actual acreages have not been calculated for the entire region.

It is too early to determine if the present outbreak is collapsing. A significant reduction in acres of defoliation has been detected in 1987. The reduction is likely due to cold temperatures during the spring and early summer. A resurgence in 1988 is possible.

Future outbreaks will continue to occur when climatic conditions favor population increases in areas of susceptible host type.

Cause of Outbreak: Vast acreages of highly susceptible stands can be found within the region. Selective harvest practices during the first half of the century removed the desirable pine components and accelerated succession. In these high-graded stands the timber value is too low to warrant stand improvement cuts. These practices coupled with active fire prevention and suppression has increased the contiguous acres of

susceptible host type. When budworm populations increased in these susceptible stands natural regulating factors, such as parasites, preditors, diseases, etc., were unable to suppress the outbreak.

Current Control Program(s): No direct control programs for the suppression of budworm populations have occurred on Federal lands within Region 4 since 1979. Most forests are relying upon silvicultural methods for long term mitigation of budworm impacts.

Impacts:

Number of Acres Affected: See current situation.

Physical Loss: In 1982 on the Boise and Payette NF annual radial growth was reduced by 30 - 40 % for true firs and 15 % for Douglas fir as a result of repeated budworm defoliation. Top kill was common on true firs affecting 10 - 20 % of sampled trees. In 1982 mortality was infrequent. Information gathered since 1982 indicate that mortality is more common. Impact plots throughout southern Idaho are scheduled to be remeasured during the next 5 years.

Control Response:

What control(s) were taken on this outbreak(s)? Approximately 139,000 acres were aerially sprayed in 1979. No direct control programs for the suppression of budworm populations have occurred on Federal lands since 1979. As a result of the 1978 WSB EIS, the Boise and Payette NF accelerated harvest of highly susceptible stands and incorporated cultural treatments into prescriptions. See current control program.

What control could have been taken? Measures to limit the proliferation of "high risk" stands (i.e. timber harvest, thinning, prescribe burns, promoting non-host species) could reduce the impact and help control the magnitude of the outbreak(s).

What would have happened if no control had been attempted? If a stand is budworm infested or susceptible to budworm defoliation the site-specific silvicultural prescription must deal with that condition as part of normal management. Under normal management the following impacts will occur:

1. A loss of insect-killed timber not already committed for harvest.

2. A possible reduction in allowable cut on affected acres due to growth loss.

3. Possible loss in cone crops for natural regeneration and seed collection.

4. Increased need for fire suppression created by fuel-type changes.

5. Short term impairment of recreation and aesthetic values.

6. Possible minor increases in watershed yields.

<u>What could have been done to preclude this outbreak</u>? See what control could have been taken.

<u>What could be done to prevent future outbreaks</u>? We will never be able to prevent outbreaks within Region 4 because vast acreages of susceptible host type are in areas having management constraints. However in high value areas we can limit the proliferation of highly susceptible stands by: 1) defining stand objectives, 2) where in agreement with stand objectives and forest plans culturally manipulate stands to avoid the highly susceptible conditions.

<u>Region 6</u>

<u>Status of outbreak(s)</u>: About 448,000 acres are being defoliated in Washington but only the area near Rimrock Lake on the Wenatchee National Forest considered to be economically important. The infestation covers about 10% of the host type. In the Blue Mountains and the east slope of the Cascade Mountains of the Mt. Hood NF and Warm Springs IR about 5,570,000 acres are being defoliated; about 75% of the host type. About 2.7 million acres were considered for treatment in 1987 with about half qualifying for treatment based upon economic consideration.

<u>Course of the outbreak(s)</u>:

<u>When did outbreak(s) start</u>? An outbreak exists covering large parts of the Ochoco, Malheur, Umatilla and Wallowa-Whitman NFs and adjacent state and private lands in northeastern Oregon. Defoliation was first detected on 6,000 acres near Cover, Oregon in 1980. The infestation increased to 6 million acres in 1986. In 1988 we expect defoliation intensity and extent to diminish. By 1990 we expect the populations to be collapsing due to lack of suitable host foliage. In ten years the population should be back to endemic.

Defoliation in the current outbreak was first detected from the air on about 66,000 acres on the east slope of the Cascade Mountain Range in Oregon in 1983. This outbreak has increased to about 910,000 acres on the Mt. Hood NF, adjacent state and private lands and the Warm Springs Indian Reservation. By 1988 and 1989 the infestation should be reaching its highest intensity and extent. In ten years the population should be back to endemic.

In 1978 areas of defoliation began appearing in the vicinity of the Tonasket RD of the Okanogan NF, have been detected on varying acreages since that time with 448,000 acres detected in 1986. This population seems to be operating in a chronic low level outbreak, somewhat noncharacteristic for the Region. We cannot predict what this population will do.

On the Naches RD of the Wenatchee NF 12,000 acres were mapped in 1984, 134,000 in 1985 AND 80,600 IN 1986. This is the first budworm defoliation reported in the area. Since this is the first recorded outbreak in the area we cannot predict its behavior.

<u>What are the expectations for future outbreak(s)</u>? Generally we believe that outbreaks will continue as host conditions return to the status that

releases the population from its controlling factors. If the stands are not managed to reduce the succession towards climax the outbreak frequency will remain high.

What caused this outbreak? See P 111 and 114 in USDA Tech. Bull. 1694.

Describe the current control program(s). The alternatives considered in analyzing the current infestation were do nothing and treat high priority areas with chemical or biological insecticides.

Acres treated by type of treatment :

YEAR	ACRES	COST PER ACRE
1982	178,500	$7.82
1983	524,600	$9.87
1985	41,000	$11.80
1987	138,100	$16.00

Percent of total infested acres treated : This is meaningless as we have been constrained in treating parts of the outbreak by available funds and human resources. Our experience suggests that control is lost when projects exceed approximately 500,000 acres.

Costs (expenditure per year by type of treatment since start of current outbreak(s): See above.

Impacts

Describe the impacts of the current outbreak(s), to 1987, that are certain.

Number of acres affected: 2,688,115

Physical loss (volume of timber, forage, water) 1,487,102 MBF OF TIMBER.

Use loss (recreation, wildlife, aesthetics): The intangible of aesthetics and responsibilities to adjacent landowners was used as a justification to spray areas surrounding Rimrock Lake on the Wenatchee NF and Starr Ridge on the Malheur NF.

Monetary value of losses (total and per acre): Timber volume losses have a PNV of $17,603,187 given a 4% discount rate.

Other (fire risk, hazard trees): Considered negligible.

Control Responses

What control(s) were taken on this outbreak(s)? Insecticide applications.

What control could have been taken? Control projects were taken to the extent that funding was made available.

What would have happened if no control had been attempted? Losses that could have been prevented by insecticide application would have been foregone.

What could have been done to preclude this outbreak? Probably nothing as we do not know with certainty what causes outbreaks. We surmise that stand conditions as well as some meteorological or climatic phenomena "trigger" or release the populations from their natural enemies and other controlling factors.

What could be done to prevent future outbreaks? We believe that managing forest stands to avoid succession to a climax forest of host trees is the best bet for reducing the severity of outbreaks of budworm. This of course must be tempered by the reality of other pests also impacting the same stands as well as the objectives and constraints of managers.

Treatment Options--Describe available treatment techniques, accomplishments, and costs:

Four treatment options or strategies are generally recognized. These are:

1. No action - No efforts are made to reduce budworm populations or damage levels. Damage caused by outbreak populations is accepted. Generally, outbreaks will eventually collapse from natural causes.

2. Direct suppression with insecticides - Mostly commonly, this strategy calls for aerial applications of either chemical or biological insecticides. Suppression has been conducted on large areas or "entomological units" in efforts to reduce outbreak populations, and on small acreages or "targeted spraying" where the objective has been to reduce stand or resource damage on these "high value" acreages. Ground treatments or individual tree treatments have been conducted using both chemical and biological insecticides with the objective of protecting "high value trees."

3. Indirect management through silviculture - Forest stand characteristics which are associated with high susceptibility and vulnerability can be modified by silvicultural treatments to reduce damage from future outbreaks. General recommendations (from USDA Forest Service Technical Bulletin 1696) are as follows:

Use the most appropriate silvicultural system for the local community or habitat type in mature and overmature forests.

In general, convert mature and overmature stands of budworm host species to new stands of mixed or nonhost species, where possible.

Favor even-aged silvicultural systems that are ecologically sound and compatible with other management objectives.

Try to develop a mosaic of age classes and host and nonhost stands.

Strive for mixed-species stands through regeneration and cultural activities and attempt to maintain less than one-third host species.

Favor seral species for plantings and as leave trees in thinnings, cleanings, and other partial cuttings.

In shelterwoods, favor seral species for leave trees and remove residual host overstory no later than 10 years after regeneration is established.

Consistent with other management objectives, make treatment units as large as possible.

Create a buffer zone by reducing basal area of host species in adjacent stands within 330 feet (100 m) of the boundary of treatment units.

Select against heavily defoliated trees during partial cuttings and thinnings.

During stand development, maintain vigor through such systems as precommercial thinning to wide spacings, maintaining a low ratio of host to nonhost growing stock (1 to 3 or 1 to 4), and commercial thinnings to reduce competition at appropriate intervals.

4. IPM - Forest Service policy for dealing with destructive pest outbreaks is IPM (FSM 3400). To implement IPM, clear resource objectives along with information/analysis on pest situations and how these pest situations will impact resource objectives is necessary. Treatment options under an IPM strategy may include one or all of the previously mentioned options.

Frequency of treatment: Direct suppression programs during the last 6 years.

Year	Region	Acres Treated	Cost/Acre
1987	R-3	13,400	$16.10
1987	R-6	138,000	16.00
1986	R-3	2,800	12.14
1985	R-3	23,320	10.08
1985	R-5*	89,000	2.70
1985	R-6	41,000	11.80
1984	R-3	34,500	7.12
1984	R-3	240,900	5.87
1983	R-3	33,500	8.10
1983	R-6	524,000	9.87
1982	R-3	71,000	8.96
1982	R-3	178,000	7.82

*R-5's project was conducted against Choristoneura carnana v. californica. Management strategy and treatments were identical to C. occidentalis strategies.

Accomplishments with direct suppression treatments: No specific data exists, however, the following general accomplishments apply:

1. Reduction of larval populations.

2. Reduction in radial growth losses.

3. Reduction in foliage losses, top-kill, and tree mortality (smaller size classes).

Accomplishments associated with direct suppression treatments are short-term (2-5 years) only.

Indirect management through silviculture is widely applied in all western Regions. This approach is considered the only viable technique to reduce losses in future outbreaks. Region 1 reported 3,960 acres treated annually. No other data is available. While silvicultural treatments are ongoing in all Regions, no method exists for tracking silvicultural treatments. Cost per acre estimates are also unavailable.

Technology Information: The basic concept of reducing stand susceptibility, along with generalized prescriptions to do so, are in place. However, the following additional technology is needed, at least in some areas of the West:

1. Validation of hazard rating systems for WSB.

2. A useable growth and yield model for mixed conifer in the central and southern Rocky Mountains.

3. Documentation on the long-term effects of silvicultural manipulation in preventing or reducing the frequency of WSB outbreaks.

4. More effective and efficient transfer of current information to the Forest and District Staffs regarding management options and opportunities in preventing WSB outbreaks.

5. Effective and efficient methods of integrating WSB management with the timber management process.

6. A more accurate early warning system predicting population increases.

7. Accurate predictions of impact based on population sampling and defoliation patterns.

8. Using an analysis unit concept, an accurate method of determining what effects silvicultural manipulations on a percentage of the highly susceptible stands will have on the course of present and future outbreaks.

Describe the obstacles, if any, to the use of existing technology for preventing outbreaks: There are three areas where obstacles are perceived.

1. Use of insectides in forest environments: The use of insecticides has become an emotionally charged issue because of perceived adverse environmental and human health impacts. Environmental groups have largely opposed the aerial application of insecticides, particularly chemical insecticides. As a result, many forest managers are reluctant to consider and select management alternatives calling for aerial insecticide applications, knowing these decisions will be unpopular and likely result in appeals.

2. Markets for wood products derived from host tree species: Most host tree species have low timber values. Implementation of silvicultural treatments (identified as the best approach for prevention of future outbreaks) hinges on the ability to sell timber sales comprised of host species. Without good markets or demand, these sales are likely sold below costs. Other issues in this area are: 1) Cable-Logging, 2) road construction and access, 3) planning and scheduling of timber sales and other silvicultural to optimize efforts to treat highly susceptible stands.

3. Technology transfer and utilization by field units: Recent technology developed during the CANUSA Budworms Program, such as population and impact models, and stand hazard models, presents some obstacles to implementation at the field level. These obstacles include training on availability and use of models, additional time and manpower requirements to collect additional needed data on pest or stands, and the workload of analyzing these data for inclusion in forest planning and/or scheduling of activities.

<u>Describe limitations placed on effective response to the pest by-laws, policies of the Forest Service, and policies of other government agencies</u>: An excellent discussion of this topic exists in "Western Spruce Budworm and Forest Management Planning," USDA Forest Service Technical Bulletin 1696, Chapter 6, p. 44-63. Two pieces of legislation have a significant effect on pest management, the National Environmental Policy Act of 1969 requires federal agencies to identify and disclose the environmental effects which might be derived from agency actions. The limitations on Forest Service actions resulting from this act are well known and well litigated. The National Forest Management Act of 1976 (NFMA) is a second piece of legislation limiting or directing certain Forest Service actions. The key point of NFMA if the requirements for forest resource planning and forest plans. The act requires integrated resource planning which includes integrating forest pest management into the overall plan. To a large extent, this act as it relates to forest pest management has not been fully implemented.

<u>Perceived Issues</u>

a. To what extent is aging of the forests related to the incidence of forest pest outbreaks? As stands and forests approach climax conditions, susceptibility to, and the incidence of, WSB outbreaks increase. Associated factors include unevenaged structure, overstocking, and absence of nonhost species due to past logging practices and fire suppression.

b. To what extent do forest plans and the NFS planning process address forest pests and forest health? The extent to which forest plans and the

NFS planning process address WSB and forest health varies from forest to forest and region to region. In Region 1, most plans discuss major forest pests and address plans to reduce insect-caused damage. In Region 2, WSB was not an issue in any forest plans. Most of the current forest plans in Region 3 include general standards and guidelines for dealing with major insect and disease problems, including WSB where it is considered detrimental to resource values. In Region 4, most forest plans address insect and disease problems, but projections were made based upon economic models which did not adequately address insects and diseases as part of forest dynamics.

In most plans, "Forest Health" per se, is indirectly addressed through timber management standards and guidelines to improve the overall vigor of the forests.

c. What triggers a decision to take action against a forest pest? In some areas, management decisions to take action against WSB have been based on the values at risk and the expected outcome of alternative actions. However, in most areas, WSB becomes a concern only when it attains outbreak proportions and resultant damages become intolerable to forest managers, impacted publics, or private industry. Action, usually corrective rather than preventive, is then initiated in response to public outcry, political pressure, or economic losses.

d. How does the public's knowledge of forest ecology and forest management influence decisions affecting forest health? The public, in general, has limited knowledge of forest ecology and forest management, and while the influence they have on decisions affecting forest health can, at times, be substantial, their opinions are often based on emotions and misinformation. In contrast, many varied special interest groups are extremely knowledgeable about forest ecology and management. These groups working in concert, and sometimes in opposition, exert considerable pressure on the forest managers resulting in both positive and negative effects on forest health.

e. To what extent does the technology exist for enhancing and maintaining forest health? See previous response re: Technology Information.

f. How have man-caused changes in natural dynamics of the forest ecosystem influencing fire activity, ecosystem diversity, and nutrient cycling affected the incidence of pest outbreaks? Man-caused changes such as fire suppression and high-grade logging have changed the natural dynamics of the forest ecosystem, resulting in large, contiguous areas of WSB-susceptible stands. WSB outbreaks within many of these areas have become more widespread, more severe, and of longer duration in recent years. Fire suppression has resulted in greater stocking densities, reduced vigor, greater percentage of shade tolerant host species, more mature stands, and reduced horizontal and vertical diversity. High-grading has increased susceptibility to WSB outbreaks by removing the more economically valuable pine from the stands, thus reducing species diversity and increasing the component of host species over large areas.

g. How has the increased public involvement in the forest management decision-making process affected forest health? Increased public involvement has complicated the forest management decision-making process, perhaps to the detriment of forest health in many areas. Management objectives of different publics and special interest groups vary considerably and determining compromise decisions is extremely time consuming and sometimes in conflict with "our concepts" of forest health. Increased public involvement has led to increased restrictions on management alternatives and activities such as annual cuts, road building and types of harvesting, which have resulted in less healthy, more susceptible forests.

h. How have public perceptions about pest-caused damages, losses, value of losses, cost of treatment or prevention, and risks of treatment affected forest health? Public perceptions about pest-caused damages, losses, value of losses, cost of treatment or prevention, and risk of treatment vary greatly from area to area and among different publics. Defining objectives and selecting acceptable management alternatives which will satisfy the different publics is difficult. In some areas, the public seems unconcerned about WSB outbreaks. Reasons for this lack of concern may vary from apathy to a perception that insect outbreaks are a part of the natural dynamics of a forest and that WSB will help regulate forest health. In other areas, public perceptions have created healthy dialogue regarding public expectations of forest health, leading to more intense forest management. In still other areas, public perceptions are of a static forest that can, and should be kept "healthy" by insect suppression using pesticides, regardless of the cost. This is in direct conflict with still other publics who are opposed to any use of pesticides on forest lands.

i. Do the frequency and intensity of outbreaks by this pest vary by land ownership? What factors explain this difference? Frequency and intensity of WSB outbreaks do not seem to vary by land ownership.

MOUNTAIN PINE BEETLE

Robert D. Averill

The mountain pine beetle(MPB), Dendroctonus ponderosae Hopkins, is the most serious tree killing insect pest of western forests today. The average annual loss since the turn of the century may be as high as 1.5 billion board feet. In this review, we consider its' role in the United States, recognizing that this insect is distributed, from northwestern Mexico to northern British Columbia and western Alberta in Canada.

Background

Found from the Black Hills of South Dakota and western Nebraska, west to the Pacific coast, border to border, MPB finds suitable host material from nearly sea level to over 11,000 feet elevation. Its major hosts include lodgepole, ponderosa, sugar and white pines. Limber, Coulter, foxtail, whitebark, pinyon, bristlecone, and Scots pine are also attacked. During heavy infestations this insect has also attacked adjacent Douglas-fir, true firs, spruce, larch, and incense cedar, but because these are not true hosts, completion of a life cycle from these species seldom occurs.

Lodgepole pine, Pinus contorta Dougl. ex Loud, occupies about 13 million acres in the Rocky Mountain and Pacific Coast regions(SAF cover type 218). It is one of the most widespread species in the western U.S. It has a remarkable ecological amplitude, growing in many different environments. In terms of timber potential, it ranges from poor to very good. The species is not difficult to regenerate naturally or artifically. An even-aged silvicultural system is preferred for the species, but both even-aged and uneven-aged systems can be used to regenerate lodgepole pine. Not all cutting methods under both systems are applicable in every stand. And some cutting methods cannot be used in lodgepole stands under most circumstances. Group selection is the only viable uneven-aged method for this species, and then the mountain pine beetle and dwarfmistletoe risk must be minimal. The even-age methods of clearcutting or shelterwood are applicable. However, in old growth where the risk of mountain pine beetle and dwarf mistletoe is high, clearcutting or regenerating the stand through prescribed fire are about the only viable alternatives.

Ponderosa pine grows naturally from western Nebraska to the Pacific Coast and border to border, and is the most widely distributed pine in North America. The SAF recognizes several forest cover types for this species.

Pacific ponderosa pine(SAF cover type 245) extends from the Klamath Mountains of Oregon south to near San Diego. It grows best on the western slopes of the southern Cascades and Sierra Nevada. It occupies about 1.5 million acres. With the long growing season of this region, its primary limiting factor is available moisture. Uneven-aged management systems are poor here as the species grows slowly in the presence of an overstory. Thus, even-aged systems are preferred. Most managed stands in this area are regenerated by planting, as harvest may not coincide with a good seed crop. In this portion of its range,

western pine beetle, Dendroctonus brevicomis LeConte, is a more common than MPB. Infestations involving a mixture of pine beetles are not uncommon.

About 7 million acres of ponderosa pine cover type 237 is present in eastern Oregon, Washington, and northeastern California. Both even-aged and uneven-aged management systems are practiced here, depending upon site and stand conditions. Considerable mixing with other species occurs at the lower and upper elevational ranges in this area. The western pine beetle, dwarf mistletoe, as well as Armillaria root rot create challenges in some stands.

Further inland, Montana, Idaho, and eastern Oregon and Washington there are about 20 million acres of mixed ponderosa pine and Douglas-fir, Pseudotsuga menziesii var glauca (Beissn.)Franco. Two SAF cover types are recognized, Interior Ponderosa Pine-237 and Interior Douglas-Fir- 210. At the lower elevations ponderosa pine is the climax species and as elevation is increased it is replaced by Douglas-fir. Climate and available soil moisture strongly regulates the distribution of these trees, and mixed stands involving western larch, lodgepole pine and grand fir occur on more moist sites. Both even-aged and uneven-aged management systems are applicable in this area of ponderosa pine habitat. Site and stand conditions will dictate, as well as the presence or absence of dwarf mistletoe the mangement system selected.

SAF cover type 237 includes southwestern ponderosa pine occuping about 11 million acres in Arizona, New Mexico, Utah, and Colorado. Growing in pure stands where it is climax, but being replaced by more xeric or mesic species at lower or higher elevations, this species can be found in association with juniper, Gambel oak, Douglas-fir, spruce, quaking aspen, white pine, lodgepole pine, and true firs. Both even-aged and uneven-aged management systems have been applied to the type in this portion of its range. Due to the more mesic conditions of the southwest, the most effective way to regenerate even-aged stands is a two-step shelterwood. Since about one third of the commercial forest area is infected with dwarf mistletoe, the overstory cut cannot be delayed to long. In such situations where this disease and MPB are strong factors, patch clearcutting may be preferred. Regeneration of clearcuts is further affected by variable seed production years, poor moisture regimes, and a tendancy to convert to grass, resulting in mixed success over time.

In the Black Hills of South Dakota and eastern Wyoming lies another 1.5 million acres of ponderosa pine. Surrounding this area is another 250,000 acres of the type on butte-top and scarp sites. This makes up the rest of SAF cover type 237. Truely one of the unique silvical features in this portion of the ponderosa pine range is its dependable seed production. This, along with favorable spring & summer moisture regimes, allows for abundant reproduction. Another unique advantage here is the absence of dwarf mistletoe. With over a century of timber harvesting experience, this area has seen the spectrum of silvicultural systems applied: clearcutting from 1876-1896; seed tree cutting from 1897-1907; shelterwood cutting from 1908-1925; individual tree selection from 1926-1955; and back to shelterwood since 1956.

Sugar pine, Pinus lambertiana Dougl., is found from the west Cascade Ranges in Oregon through the Sierra Nevada and North Coast Ranges in Southern California in the Sierra Nevada mixed conifer (SAF cover type 243) and Pacific ponderosa pine/Douglas-fir(SAF cver type 244). This species occurs as single trees or small groups but never in pure stands over extensive areas. White pine blister

rust, an introduced disease, is spreading and intensifiying over much of the range of sugar pine, killing trees up to the small pole size class. Since it is commonly found in mixed species stands, both even-aged and uneven aged management systems have been applied. The criteria being set by site, stand condition factors, as well as management objectives.

Western white pine, Pinus monticola Dougl., is found along the west coast ranges from the Canadian border to the southern Sierra Nevada Mountains of California and western Nevada. Further inland, it occurs from Northeastern Washington therough the panhandle of Idaho and scattered areas of western Montana, southeast Washington and northeast Oregon. It generally occurs in mixed stands, making up to half the stand by volume. With the wide variety of species with which it grows, considerable latitude is available in the choice of silvicultural system selected to meet the management objectives, site and stand conditions. Clearcut regeneration is preferred where improved genetic stock is desired in the next stand.

The distribution of the primary host types for MPB by State and ownership is shown in Table 1.

Both ponderosa pine and lodgepole pine have enough genetic variation within their respectice gene pools that varieties of the species are recognized. The more severe barkbeetle outbreaks occur within Pinus ponderosa scopulorum and Pinus contorta latifolia.

With over 56 million acres of suitable host in the western United States one can expect some variation in the life cycle. Usually one year is all that is needed to complete a life cycle. But, in the warmer areas of California where sugar pine is the host, two generations may be produced annually. At the higher elevations, the insect may take two years to complete it's life cycle.

In some areas where MPB is found, California, Colorado, Arizona, the insect must compete with the roundheaded and western pine beetles. Often these other beetles will displace MPB significantly, depending upon a variety of factors.

Table 1. Distribution of major hosts for Mountain Pine Beetle in thousands of acres by State in the west.

Species	National Forest	Other Public	Forest Industry	Private Owner	withdrawn/ noncommercial	Total Acres
			WASHINGTON			
Ponderosa	88.0	49.0	69.0	62.0	95.0	363.0
Lodgepole	126.0	18.0	20.0		111.0	275.0
White	35.0				1.0	36.0
Sugar	NO DATA AVAILABLE					
			OREGON			
Ponderosa	3540.0	1044.0	1014.0	1128.0	875.0	7601.0
Lodgepole	1679.0	271.0	296.0	249.0	367.0	2862.0
White	57.0				6.0	63.0
Sugar	NO DATA AVAILABLE					
			CALIFORNIA			
Ponderosa	910.1			395.4		1305.5
Lodgepole	189.0		10.0	62.0	766.0	1027.0
White	27.2					27.2
Sugar	4012.0	94.0		2647.0		6753.0
			IDAHO			
Ponderosa	851.5	213.0	86.2	407.5	601.8	2160.0
Lodgepole	1882.4	65.0	19.4	159.6	1638.6	3765.0
White	123.2	65.6	50.3	36.2	19.8	295.1
			MONTANA			
Ponderosa	340.0	509.7	433.2	1118.5	316.7	2718.1
Lodgepole	3100.0	297.9	108.7	655.3	2281.9	6443.8
White	34.3	2.1	14.7			51.1
			SOUTH DAKOTA			
Ponderosa	914.6	71.8	11.6	172.5	78.5	1249.0
			WYOMING			
Ponderosa	235.1	156.4	37.5	503.7	81.9	1014.6
Lodgepole	1283.0	82.1	5.5	96.1	2203.2	3669.9
			NEBRASKA			
Ponderosa	30.8	7.7		107.6	29.5	175.6
			COLORADO			
Ponderosa	952.2	190.5		1161.7	256.8	2561.2
Lodgepole	1270.1	93.3		361.2	526.1	2250.7
			UTAH			
Ponderosa	324.1	71.5		31.2	129.1	555.9
Lodgepole	424.7	11.0		24.7	242.7	703.1
			NEVADA			
Ponderosa	23.7	2.9	4.4	29.3	14.3	74.6
Lodgepole	3.6	0.2	0.6	3.9	46.1	54.4
White	0.7					0.7
			NEW MEXICO			
Ponderosa	1809.7	667.9		1066.7	837.0	4381.3
			ARIZONA			
Ponderosa	2149.8	1140.1		142.2	767.6	4199.7
Total	26416.8	5124.7	2181.1	10621.3	12292.6	56636.5

The female beetles initiate attack on a susceptible host tree. Females attract males and once mated, construct vertical egg galleries beneath the bark. The combination of male and female pheromones, and volatile terpenes of the host, produce a strong attractant which results in mass attack on individual trees. A mass-attacked tree may have ten or more new attacks per square foot of bark surface for as high as 25 or more feet on the bole. The adult beetles carry with them several blue staining fungi which block the conducting tissues of the host. The females lay eggs in niches along the sides of the galleries during the summer and early fall. The eggs hatch in ten to fourteen days. The newly hatched larvae construct galleries at right angles to the main egg gallery. Overwintering larvae reduce their body moisture content to protect them from ice crystals. In the spring they absorb moisture, continue larval development and become pupae. By July, the pupae are transformed into adults. During a short period between July 15 and August 25, the adults emerge, and fly to new host trees, starting their life cycle once again.

Under endemic conditions, trees selected for attack are generally overmature, weakened by lightening, root disease, or some other stress inducing condition. During epidemics, more vigorous trees are attacked as well as the less preferred species.

Mountain pine beetle outbreaks are not cyclic--rather are related to stand conditions of host type. As host growth rates slow in response to overmaturity, competition, disease, or other disturbance factors, hosts become more susceptible to beetle depredation. Once initiated, an epidemic will kill increasingly less susceptible host trees, over a 5- to 10-year period, until the only trees left in the stand are those in which the phloem is too thin to maintain brood development. Though usually those trees are in the smaller diameter classes, some old-growth trees may be relatively unsusceptible as well. At that point, in that stand, beetle populations once again decline to an endemic status.

It should also be noted that once an outbreak commences it generally stays in stands where there is crowding among stems. Adjacent stands under a managed condition are seldom attacked except along the edges where they interface with an unmanaged condition. For instance, within managed stands of Ponderosa growing in the Black Hills, one only finds attacks where the basal area exceeds 110-120 sq ft. Those portions of the stand where the basal area is below 90, are seldom attacked unless an individual tree is injured. Unmanaged stands will lose 30 to over 50 percent of the trees over four inches d.b.h. And, within an attacked stand, losses of 100 percent of the host can occur in pockets of several acres.

Since the insect is native to North America, it is usually found at some level within a watershed occupied by its host. Outbreaks appear to be principlly triggered by overmature or crowded stands that are further stressed by a lack of available moisture during critical periods to the insect and its host. Pheromone attractions of attacking beetles are so strong that seldom is an individual tree attacked. More often, epidemics build from small "spot" infestations of several trees which increase in size over the life of the infestation. Population collaspes always seem to occur after host depletion has taken place in unmanaged stands, or, abnormally cold or wet weather has caught the population offguard. While predation and parasitism by other vectors

influences the MPB, these factors alone have never been associated with the collaspe of an outbreak. In addition, mans' efforts through direct control using chemicals, fire, and removal of infested material have been of short term value since the stands are seldom brought into proper growing condition during the life of an outbreak. Recent efforts at emphasizing manipulating the infested stands as well as high risk stands adjacent to infested has resulted in outbreaks within treated stands collasping sooner than expected than under a direct control strategy alone.

Acres infested by Region and host type in 1986 are displayed in Table 2.

Table 2. Acres infested by Mountain Pine Beetle in the western United States, 1986.

Region	Ponderosa	Lodgepole	White	Sugar	Other	Total
1	43400	833400	4200		4500	885500
2	36813	164195			9909	210917
3	2000					2000
4	115765	540575			71	656411
5		20000				20000
6	287760	1422590	49030	1130	380	1760890

Region 1:
Outbreaks in Region 1 inreased in the 1960s and 70s' to a point where nearely three million acres were infested. By 1981, many infestations in Montana had begun to decline, though more than 2.4 million acres were still infested. Affected acres in northern Idaho increased slightly. Through the early 1980's, beetle infestations in Montana continued a gradual decline--dropping to 1.3 million acres in 1984, and below a million, to 934,000 in 1985. Northern Idaho infestations rose slightly to 28,000 acres in 1984 before beginning to decline. Currently, more than 885,000 are infested Regionwide.

At the present time, many infestations are declining as a result of host depletion and management activities. Localized infestations, however, on the Bitterroot, Deerlodge, Flathead, Kootenai, and Lolo National Forests, and the Northern Cheyenne Indian Reservation--and adjacent State and private lands increased significantly from 1985. Though some infestations will continue to intensify for the next few years. Regionwide we anticipate a gradual declining trend in infested acres in 1987.

Within Region 1, 22.4% of the lodgepole type; 9.6% of the Ponderosa; 2.6% of the Western white; and 3.9% of other pine types are currently infested.

<u>What are expectations for future outbreaks:</u> Infestations are expected to decline for the next several years, then increase for the 1990s.

<u>What caused outbreaks</u>: Mountain pine beetle outbreaks, particularly in lodgepole pine stands, are a naturally occurring event in the sequence of events which replace overmature stands with younger, more vigorous ones. In the ecological cycle of lodgepole pine stands--and perphaps other pine

species--beetles kill trees as they become mature, fire removes the dead trees, and seed left behind regenerates the stand. In a cycle devoid of man's intervention, areas of host species would probably be made up of a mosaic of size and age classes. Beetles would continue to play an integral role in stand replacement, but on a much smaller scale. Around the turn of the century, we became particularly adept at eliminating fire fromm the chain of events which would have perpetuated the mosaic pattern of various age and size classes. As a result, vast acreages of lodgepole pine matured at approximately the same time in the Northern Rockies. The resulting devastation is well recorded.

Current control programs: Efforts to forestall losses to mountain pine beetles have ranged from application of pesticides to infested trees, to falling and burning, and salvage of infested stands. We now realize the best chance of reducing losses is through the silvicultural manipulation of threatened stands in a preventive mode. Preventive silvicultural treatment not only remove trees before they are killed, thereby maintaining their economic value, but reduce the available food supply of the beetle and indirectly reduce populations in that manner. Silvicultural treatments include stand removal and partial cutting. Some preventive treatments with carbaryl are conducted in areas of high aesthetic values such as campgrounds, administrative sites, etc.

Acres treated by type of treatment: Chemical prevention, Regionwide - less than 500 acres total, since 1970. Silviculturally (salvage, prevention, hazard reduction), Regionwide - just over 99,000 acres since 1970.

Percent of total infested acres treated: Varies from Forest to Forest--ranged from 1 percent to 20 percent of infested area. Regionwide averaged about 7 percent since infestations began.

Costs of treatment: Only estimates of treatment costs are available, and they vary greatly by Forest. Total costs (above normal operations) probably exceed 1.8 million dollars, averaging more than $100,000 per year since 1970.

Impacts

Number of acres affected - At the peak of the mountain pine beetle infestations in the Northern Region, approximately 2.5 million acres were infested. Though infested acres prior to that peak (1981), and since, have been numerous, the area encompassed by the infestations have totaled only slightly more--just over 3 million acres.

Physical loss - Recent ground surveys (1986) show, for those areas of active beetle infestation surveyed, a combined beetle-caused mortality of 80 standing-dead trees per acre. That includes several years of accumulated mortality on each acre. That data indicates an estimated 240 million trees killed in the most recent series of beetle infestations (from 1970 to the present). Accounting for trees killed which were cut by firewood cutters or fell before tallied in a survey, that figure may be conservative. Using an estimated 50 board feet of volume per tree, which is an average figure for a 9 inch d.b.h. lodgepole pine, that mortality represents 12 billion board feet. Once again, that figure is no doubt conservative because a significant amount of total mortality was larger diameter ponderosa pine and western white pine for which accurate estimates are not available.

Use loss - All forests queried replied that while few reliable dollar estimates have been made, other resources such as wildlife, watershed, recreation and visuals have been adversely affected by beetle-caused mortality. Some short-term benefits, in the form of increased forage production has occurred in affected stands, but once dead timber begins to fall, that resource is also lost to big game and livestock. Additional losses include hiding and thermal cover for big game and disturbance from increased logging as dead and dying timber is salvaged. Costs incurred in keeping roads and trails open has increased markedly. As stands experiencing high amounts of mortality lose value as big game habitat, they likewise become less valuable in hunter recreation value.

Monetary value of losses - Monetary loss estimates vary somewhat from Forest to Forest, but most express losses in terms of the difference between stumpage rates for green timber, contrasted to those for dead. Green lodgepole pine for example, currently sells for between $25 and $37 per MBF (thousand board feet). Beetle-killed lodgepole pine on the other hand, if sold at all, brings $0.50 to $1.00 per MBF. An "average" figure for volume per acre killed is approximately 4 to 6 MBF. A conservative estimate of 4 MBF per acre at a reduced value of $30 per MBF equals $120 per acre value loss. Actual dollar loss per acre varies considerably by forest and is dependent upon amount of dead timber salvaged, access, alterations in sale programs, opportunity costs foregone, etc. Loss estiamtes that may be reasonably calculated range from $500,000 on one Forest, to 6 million dollars on another. Those figures do not include stands in which mortality occurred but could not be economically accessed. Using the figure of 12 billion board feet killed (from previous question) and reduced sale value of $30 per MBF, an estimated 360 million dollars in lodgepole pine value may have been lost since 1970 in the Northern Region. Once again, additional reductions in western white pine and ponderosa pine timber values have been significant.

Other impacts - Increased fire risk in managed stands has obviously been reduced. However, in stands purposely not managed (parks, wilderness areas, etc.) or in ones not feasibly managed because of economic constraints, eventual stand replacement fires are virtually inevitable. In an ecological sense, the net effect of such fires will be positive. Where man-made structures, facilities, or other resources are threatened, however, impacts may be more costly. In developed recreation areas, costs of hazard tree removal, replacement of facilities destroyed by falling trees, or costs associated with mortality prevention has been high. Preventive treatments alone have averaged $5,000 per year on alternate years on one Forest. In some cases, campgrounds have been essentially clear cut and replanted at great direct expense and loss of recreational value.

Control responses

What controls were taken - Initially some direct control efforts in the form of pesticide applications or fall and burning of infested trees were attempted. For the most part, however, "control" is now achieved through silvicultural manipulations of infested or threatened stands. Infested stands are salvaged where possible. Threatened ones are harvested or thinned depending on management objectives for the stand, site and stand characteristics, and other resource considerations.

What controls could have been taken - Reasonable access, operating budgets, and available markets would have allowed more stands to be treated before they were attacked. Such "preventive" actions would have been much more effective in reducing beetle-caused losses than the "post-mortum" approach into which the land manager was often forced.

Effect of no control - Unfortunately, for all of the reasons stated above, and the fact that effective preventive silvicultural techniques have only been recently developed, only about 10 percent of the affected stands have been treated. Therefore, loses may only have been about 10 percent higher than they were.

What could have prevented the outbreak(s) - The ability to produce a mosaic of age, size, and (where feasible) species diversity over the range of beetle host type. Shorter rotations, resulting in younger, more vigorous stands would also reduce losses to the beetle.

What will prevent future outbreaks - The resolve, and wherewithal, to break up vast acreages of host type all reaching maturity at the same time. The creation of the condition previously described, i.e., age, size, species diveristy, with stands maintained in a vigorous condition and harvested at an earlier age.

Region 2

During the past two years MPB populations have declined to an area encompassing 210,000 acres. Within the infested lodgepole type, 0.8 trees/acre are infested, and in Ponderosa type 2.2 trees/acre. We think we are seeing a shift this year between activity in the two types, with increases expected in the Ponderosa type. In the Black Hills, we expect MPB to increase to the year 1999 and again reach a low point in 2006. During this next outbreak phase, up to 500MMBF will be lost under the present management system. Within the lodgepole pine type, increases in MPB activity should start about 1989. Sufficient host condition to support an outbreak exists on over 34 million acres of lodgepole. The present status of the major outbreaks is:

Outbreak	Status 6/87	Acres Inf.	% Infested	88 Trend
Uncompahgre	Static	7769	4	Increasing
High Country Project	Decreasing	152417	34	Decreasing
Black Hills	Static	16695	2	Increasing
Casper/Muddy Mountain	Decreasing	11071	20	Increasing

What caused the outbreaks?: In each of these outbreaks, stand conditions, ie old age, marginal site, high basal area, or a combination of these elements plus other factors are associated with the areas under infestation.

Current control programs: Present control programs are aimed at cultural activities designed to remove green infested material from the stand as well as manipulating the spacing of residual stems. Direct control with Lindane is expected to total less than 1000 trees in 1987 at a cost of about $25/tree. The majority of control activity is in augmenting timber sale projects where location, marking and removal of green infested costs about $5/tree. We expect that about 1500 green infested trees will be removed in this manner. In

addition an unspecified number of infested trees will be removed under the normal sales program.

Impacts:

Uncompahgre- This outbreak has operated on about 20,000 acres of land during the past seven years, generally in second growth ponderosa on the flats and unmanaged old growth on the hillsides. In addition to MPB, roundheaded and western pine beetles are present. About 10 trees/acre have been lost so far or 1.4MMBF. A little less than 5000 ac will have been treated by September through cultural or chemical control. Untreated hillsides will remain a source of infestation for the next several years, in addition to their increased fuel risk. Do to the distance from sawmills and a present low demand for pine in that area most sales have gone at minimum rates($10MBF). In the economic analysis developed for this area we made the assumption that 37,000 acres were at risk over the next 80 years and that 185MMBF would be lost with no treatment. Under the proposed management scheme modeled, only 85MMBF will be lost. There are shortcomings in the analysis which we cannot deal with such as the use of a uniform loss over time over the entire area and the added costs of planting trees where natural regeneration may not occur at a present cost of $325/ac. No other significant measurable impacts are associated with the project. A large intangible though is the creation of steady woods work in a highly depressed area of western Colorado.

High Country Project- Since 1980, over 1.7 million lodgepole pine trees have been killed in Summit, Grand, and Eagle Counties of Colorado within high risk stands, or about 6 trees per acre. In addition over 500,000 infested trees were treated through chemical, mechanical or removal in timber sales. Over 4.5 million dollars in public and private funding since 1982 have been aimed at minimizing the adverse effects of MPB by establishing insect and disease resistant forests. These efforts have been primarily applied to 51,000 acres of land at an average cost of $88/ac. A considerable number of acres are in a pipeline of activities that have not taken place yet so it is difficult to determine the total impacts, both good and bad of this project. Several factors were key in the assumptions used in the project- RVD use in the major ski areas and protecting private property values within the communities. During the life of the project, RVDs increased, and property values decreased. Whether there was a significant difference between the rates of change within the project area and other areas in Colorado has not been determined. If there was, then some of the differences could be attributed to the High Country Project. The main visible benefit of the project has been the reduction of visible dead trees in the landscape and a significant increase in the acres regenerated that would not have been regenerated without the project. Until the project is completed it will be difficult to quantify the impacts. Throughout its history the project has enjoyed public support, in spite of several appeals on timber sales that slowed progress.

Had the project not been undertaken we would have had over 50 percent stem loss on over 70,000 acres as a conservative estimate. This high level of tree loss would have occurred in Dillon Basin, Minturn, and the Vail ski complex. Losses near that level have occurred on the Blue River and the Piney River country as well as smaller areas southwest of Grandby due to inacessibility and those locations being of lower priority for treatment. In order to bring about a truely resistant forest cover type, the area needs to have 51,000 acres

regenerated each decade. Regenerating 14,000 acres per decade will maintain the cover type, but with significant MPB activity. Due to present markets and other constraints the present expectation is for about 9,000 acres per decade.

Black Hills- At the present time no control activities are directed at the MPB. Sale scheduling and KV work incorporates a response to hot spots where necessary.

Casper/Muddy Mountain- The Casper effort has been underway since 1980. Initially the control efforts were centered around the central residence portion of the mountain. The State of Wyoming has supplemented thinning and harvesting by landowners and felling and burning on steep slopes. The project was expanded to Muddy Mountain in 1986. Steep inaccessible slopes remain the challenge and cable logging is being used to reach as many of these areas as possible. Over 47,000 trees have been killed on these two mountains since 1980 and over 2800 cords of wood have been harvested from State and private lands. FPM investments in this project total slighlty over $200,000 since its' inception. Maintaining property values, fire protection, and keeping a forested appearance were the initial driving forces behind the effort. Now, people are more concerned about proper forest management and the attainment of a healthy forest.

Region 3

At the present time only one outbreak is ongoing in Region 3. This is on the eastside of the Carson N.F. This outbreak started in 1985 on the Taos Pueblo Indian Reservation and the adjacent old Taos Ranger District. Presently, 1945 acres are infested, or about 5 percent of the host type in the area. The outbreak is expected to encompass up to 5000 acres in the next five years before it subsides. Much of this area is roadless, composed of overmature pine and not under management. No control is being conducted. The impacts at this time are related to an increased fuel loading in the area. If the area was roaded, then management practices would be applied to reduce the risk to MPB on slopes less than 40 percent.

Region 4

STATUS OF OUTBREAKS

Id	Idaho	Utah	Wyoming
			Infestation and Status
1[1]	Boise - static	Ashley - decrease	Gros Ventre - decrease
2	Caribou Basin - decrease	Wasatch - decrease	Greys River - decrease
3	Challis - increase		
4	Payette - static		
5	Salmon - static		
6	Sawtooth Valley - increase		
7	Big Wood - increase		

[1] These identifying numbers are now used throughout the report to track infestations.

PERCENTAGE OF HOST HABITAT OCCUPIED, COMMERCIAL TIMBER

	48%	52%	35% Bridger-Teton
2	21%	77%	
3	15%		
4	39%		
5	29%		
6	26% Sawtooth		
7			

ACRES OCCUPIED

1	4,500	400,000	5,000
2	5,000	125,000	5,000
3	3,000		
4	1,000		
5	800		
6	3,000		
7	7,000		

COURSE OF THE OUTBREAKS

WHEN DID OUTBREAK START

	Idaho	Utah	Wyoming
1	ongoing	1978	1981
2	1979	1978	1981
3	ongoing		
4	ongoing		
5	ongoing		
6	1985		
7	1981		

WHERE DID EACH START

Infestations began in stands of high risk unmanaged pine. In LPP stands normally over 80 yrs. of age, over 8" in diameter & at a point where mean annual increment = current annual increment. In PP stands normally over 10" in diameter and with basal area = to or exceeding 180 ft^2.

1	forestwide	Greendale Junction	Gros Ventre River
2	McCoy Creek	Greendale Junction	Greys River
3	forestwide		
4	forestwide		
5	forestwide		
6	Alturas Lake		
7	Warm Springs Creek		

WHAT ARE THE EXPECTATIONS FOR FUTURE OUTBREAKS

MPB populations will continue to cycle acting as: 1) prime movers of ecological succession and 2) density dependent regulators of pine populations.

1988 - 1990

1	static	decreasing	decreasing
2	decreasing	decreasing	decreasing
3	increasing		
4	static		
5	static		
6	increasing		
7	increasing		

2000

1	increasing	decreasing	decreasing
2	decreasing	decreasing	decreasing
3	increasing		
4	increasing		
5	increasing		
6	static		
7	static		

WHAT CAUSED THIS OUTBREAK

Infestations began in stands of high risk unmanaged pine. In LPP stands normally over 80 yrs. of age, over 8" in diameter & at a point where mean annual increment = current annual increment. In PP stands normally over 10" in diameter and with basal area = to or exceeding 180 ft^2. The relationship between pest & host has been normal, considering management direction. Some events which have probably shortened the period between cycles & intensified resultant tree mortality include: (following numbers relate to each infestation below)1) economic - Frequently the value of LPP or second growth PP is too low to warrant harvest of trees before stands become "high risk". 2) cultural/economic - Stand improvement options are economically limited in areas designated as "roadless"; hence trees attain "high risk status" sooner over greater acreages. 3) cultural/climatic/economic - The prevention of forest

fires has resulted in vast acreages of "high risk trees". 4) environmental - The risk of environmental damages outweighs risk of MPB infestation.

PROBABLE CAUSES

1	1,3	1,3	2,3
2	3,4	1,3	2,3
3	2,3		
4	2,3		
5	1,3		
6	1,3		
7	1,3		

DESCRIBE CURRENT CONTROL PROGRAMS

Current control programs are integrated to include some of the following strategies: 1) chemical - use of chemical sprays to prevent infestation of high value trees 2) cultural - harvest and thinning 3) attractants - use semiochemicals to trap crop 4) repellents - use semiochemicals to repel beetles

Chemical
acres/% treat/costs

1	16/0.4/5000	444/0.1/75,000	1500 trees/.1/12000
2	0/0/0	7300 trees/.1/30000	(Bridger Teton NF)
3	0/0/0		
4	0/0/0		
5	0/0/0		
6	0/0/0		
7	0/0/0		

Cultural
acres/% treat/costs [2]

1	20-30/0.4-0.7/?	0/0/0	0/0/0
1	50-100/1.0-2.0/?	0/0/0	0/0/0
3	20-30/0.7-1.0/?		
4	20-30/2.0-3.0/?		
5	20-30/2.5-3.8/?		
6	20-30/0.7-1.0/?		
7	20-30/0.3-0.4/?		

[2] best guesses

Attractant
acres/% treat/costs

1	0/0/0	0/0/0	0/0/0
2	0/0/0	0/0/0	0/0/0
3	0/0/0		
4	0/0/0		
5	0/0/0		
6	20/0.7/<500		
7	0/0/0		

Repellent
acres/% treat/costs

1	0/0/0	0/0/0	0/0/0
2	0/0/0	0/0/0	0/0/0
3	0/0/0		
4	0/0/0		
5	0/0/0		
6	20/0.7/<500		
7	0/0/0		

Where there are zero entries in the acres/%treat/costs section then that strategy was not used in the control program.

CONTROL RESPONSES

WHAT CONTROLS WERE TAKEN
See breakdown in "current control" section.

WHAT CONTROL COULD HAVE BEEN TAKEN
Measures to limit the proliferation of "high risk" stands (ie. timber harvest, thinning, prescribed burns, promoting species diversity) could have helped prevent outbreaks.

WHAT WOULD HAVE HAPPENED IF NO CONTROL HAD BEEN ATTEMPTED
Controls being applied are really insignificant relative to the total magnitude of MPB infestations but on a local basis (developed sites) desired tree cover is being presently maintained where without controls tree mortality would be the rule.

WHAT COULD HAVE BEEN DONE TO PRECLUDE THIS OUTBREAK
See "what control could have been taken above".

WHAT COULD BE DONE TO PREVENT FUTURE OUTBREAKS
Limit the proliferation of "high risk" stands by: 1) defining stand objectives, 2) where in agreement with stand objectives & forest plans culturally manipulate stands to avoid the "high risk" condition.

Region 5

Current situation (as of 6/30/87): Tuolumne Meadows, Yosemite Nat. Park
Status of outbreak(s) : Static
Percent of host habitat occupied. : 0.005%
Acres occupied : 20,000
Course of the outbreak(s)
When did outbreak(s) start? : 1985
Where did each start? : Tuolumne Meadows
What are the expectations for future outbreak(s)? : Very likely
Where will each be (area and cycle) in 1988, 1990, ten years. : It should collapse within a year or two due to a lack of suitable hosts. If past history is repeated, it should take 40 - 60 years for the existing smaller trees to reach the size and stocking necessary to support another outbreak.

What caused this outbreak?
Discuss both primary and secondary factors

Natural stand of almost pure lodgepole pine surrounding a large meadow. No record or indication of being burned or cut during this century. Only known management was limited cutting around meadow to retard encroachment and aerial application of Malathion to control lodgepole pine needleminer around 1961. Since the mid-1960's, the Park has pursued a strict "hands off" policy.
There have been several infestations of lodgepole pine needleminer during this century. An infestation during the 1920's contributed to mortality in an area now identified as the "Ghost Forest". The most recent needleminer outbreak lasted from about 1964 to 1984.
Around 1980 some overstory lodgepole pine began to decline. MPB attacks began in 1984 and continued into 1986. 1987 is one of the driest years on record and the infestation should continue until 1988 or 1989, when a lack of suitable hosts should cause collapse. The area will be naturally revegetated with lodgepole pine because trees under 15 ft. tall aren't defoliated by needleminer and most smaller trees aren't susceptable to MPB.

Describe the current control program(s). : The only "control" program is a low-key information and education program.

Acres treated by type of treatment : 100% of the 20,000 acres are receiving no treatment other than information and education. About 5,000 acres are visible from the road and concessionaires development.

Percent of total infested acres treated : All, or none, depending on your point of view.

Costs (expenditure per year by type of treatment since start of current outbreak(s)) : Total costs of the I & E program are probably less than $10.00 to date.

Impacts

Describe the impacts of the current outbreak(s), to 1987, that are certain.

Number of acres affected : 20,000

Physical loss (volume of timber, forage, water) : Apparently 0

Use loss (recreation, wildlife, aesthetics) : Apparently 0

Monetary value of losses (total and per acre) : Apparently 0

Other (fire risk, hazard trees) : Dead trees which could strike permanent developments are felled. Fire resk normally low because of high elevation (10,000+ ft.), short season (July-Sept.), and sparse vegetation.

Control Responses

What control(s) were taken on this outbreak(s)? : None (I&E).

What control could have been taken? : Needleminer control, thinning, protective spraying in developed area.

What would have happened if no control had been attempted? : Mortality.

What could have been done to preclude this outbreak? : See above

What could be done to prevent future outbreaks? : Thinning, species diversification, break up age classes.

Region 6

The major mountain pine beetle (MPB) outbreak currently occuring in Region 6 is centered in lodgepole pine on the Upper Klamath Basin. This area includes portions of the Deschutes, Fremont and Winema National Forests (N.F.). The outbreak erupted in the mid-1970's on the Bend, Fort Rock and Crescent Ranger

Districts (R.D.) on the Deschutes N.F, and has moved to the Chemult R.D. on the Winema N.F., and the Lakeview R.D. on the Fremont N.F. The heaviest infestations are still in these districts with MPB populations building in the adjoining districts. The infestation occupied 227,390 acres in 1979 and had expanded to 3,119,470 acres in 1986. Approximately 65% of the susceptible lodgepole pine in these infested acres has been killed.

In 1984, the MPB situation was analyzed on the Winema N.F. From this process it was estimated that the outbreak would continue until the year 2000. Projected tree mortality in the absence of treatment was expected to be 50% for all trees 7 inches or greater in diameter (dbh) by 1998 and 80% by 2003.

The infestation was expected to impact lodgepole pine and only 0.3% of the pole size ponderosa pine. In 1985, a 6-fold increase in large sawlog (>22in. dbh) ponderosa mortality was noted resulting in a 14MMBF volume loss in that year. The cause of that mortality was MPB or MPB with western pine beetle, together. The reason for this change in tree species preference has not yet been determined. A possible explanation is the combined effect of the large beetle population emerging from adjacent lodgepole pines and low rainfall experienced in the last three years. Some persons believe the beetle may be evolving more aggressive behaviors.

Edaphic, economic and market conditions combined to create the situation for a MPB outbreak. The Upper Klamath Basin is a large expanse of lodgepole pine with ponderosa pine growing at the higher elevations on scattered buttes. The Basin is low elevation and flat, varying from 4500 ft. to 6,000 ft. over the entire area. Lodgepole pine is highly resistant to frost damage and is able to grow under these cold air conditions. Other factors favoring lodgepole pine in this area are the high water table and the nutrient poor pumice soils. The Upper Klamath Basin has few overground streams and those that are, are usually spring fed. This area also has many wet meadows and marshes. Lodgepole pine has a higher tolerance to these wet conditions as well as the ability to grow in nutrient poor soils. Thus, the lodgepole pine is able to maintain itself as the climax community except where ponderosa pine is able to outcompete it on the warmer,drier sites of the buttes.

Unmanaged lodgepole pine usually grows in dense stands due to its prolific seed production and thus produces small diameter stems. In previous years when large diameter trees were plentiful, the market for lodgepole pine was small or more often non-existant. Depending on the current market conditions, lodgepole pine was selling from $1-14/MBF. Management of these stands was given lowest priority.

When the outbreak began, MPB had been at the chronic infestation level for several years and the stands were in a decadent condition. The management strategy was to harvest-regenerate localized outbreaks in an effort to promote regeneration and remove some of the beetle population. In 1980 the forests accelerated their harvest of lodgepole pine and began an aggressive market development program to absorb the additional timber supply. The average volume cut on the Winema N.F. prior to 1984 was 19.7 MMBF. In 1981 the annual lodgepole pine offering on the Winema N.F. was given to the Chemult R.D. From an offering of 60-80 MMBF the cut was increased to an average of 50 MMBF on that district. Intermediate treatments, i.e. commercial thinnings, were not attempted on the Winema N.F. as the lodgepole was believed to be too old for a

growth response or the stands too decimated for the treatmentsto be beneficial. The Deschutes N.F. however is attempting to thin from below in stands where there is still enough volume left to modify the density and spacing. In 1985 when the mortality in ponderosa pine increased, emphasis transferred from lodgepole pine to ponderosa pine with priority given to the higher resk stands.

Northeast Oregon is currently on the downside of a MPB outbreak that began in 1967. The outbreak occured in primarily lodgepole pine and has lasted until all suitable hosts were killed. Some ponderosa pine growing in proximity to the lodgepole was also killed. No action was taken to control this outbreak as there was no timber values associated with the lodgepole. Salvage operations were contracted after tree mortality. No market development programs were promoted because of the low timber value perceived and the delayed perception of the outbreak potential.

This area has more typical lodgepole pine communities. They originated after fire in dense, single species stands. Lodgepole pine is an aggressive seral tree species. Its' ability to produce large amounts of seed at relatively young ages, germinate and grow under harsh conditions, and its rapid juvenile growth rate allow it to outcompete other tree species for the site. Growing in dense stands however inhibits its ability to increase diameter and thus the lower perceived value. As more and more trees approached suitable beetle habitat the beetle population increased. With increasing populations the beetle is able to exploit the more resistant trees which provide better beetle habitat and increase brood production. Thus, begins the ourbreak cycle until all suitable host type is killed.

The expectation for future outbreaks is high. Lodgepole pine generally inhabits the poorer sites which are often set aside for wilderness or removed from timber management. The beetle will continue to regulate these communities as it has in the past and the potential threat to adjacent stands will always exist. Intensive management involves maintaining stand density and spacing to a level compatible to the site productivity and managing on shorter rotations (about 80-100 years).

The MPB population in northcentral Washington has been at an endemic level for several years but is beginning to build on the Twisp R.D. of the Okanogan N.F. Again, the outbreak is building in lodgepole pine and currently infests approximately 10% of the host type. The population is expected to continue increasing in the next few years by about 10% per year.

The lodgepole pine stands in this area are also of fire origin. However, they do not form the extensive, contiguous stands found in other areas. Factors leading to this outbreak are the same as in other MPB outbreaks -- mature/overmature trees in overstocked stands. The treatment planned for this area is to harvest the high risk stands before beetle attack and to thin those stands of lower risk. The success of this treatment program will depend on the aggressiveness with which the ranger district pursues it.

TREATMENT OPTIONS

Cultural: The preferred treatment option in the western Regions for controlling MPB is through the application of sound silvicultural practices, primarily because it is less expensive in the long run. Regenerating stands through even aged management systems is preferred in most forest cover types. Partial cutting with emphasis on spacing control is a proven alternative where not all high risk stands can be treated in the first entry. Partial cutting has provided immediate relief to attack by MPB, possibly from allowing terpenes and pheromones to dissipate more rapidly, creating a less attractive situation for the beetles to respond to.

Treating infested stands with cultural methods involves the removal of green infested, old dead, and spacing control of the residual stand. The sooner a stand is entered in an outbreak, the more options are available for the manager in choosing its' future condition. In addition the presence and intensity of dwarf mistletoe and rootrot effects the choice of treatment. Waiting until an outbreak is underway in an area to apply cultural control also has the distinct disadvantage of saturating the marketplace with an oversupply of wood.

Physical: Fell, limb, and peel has been used in limited areas recently where other options were not available. Costs averaged about $28/tree. Fell, limb and expose to sun has also been used in limited areas. This does require turning of the logs to heat all bark surface to dry the phloem an adequate amount to kill the larvae. Both of these methods are labor intensive.

Fell, pile, and burn has been used in areas where smoke management limitations allow this technique. Escaped fire, scorching of adjacent trees are the primary limiting factors. As the cost of pesticide application rises, this technique may become cost effective again.

Placing infested bolts under plastic tarp sealed in the soil continues to be used by landowners. Inadequate exposure to sunlight and allowing the tarp to come in contact with the infested bolts can reduce the effectiveness of this technique.

Chemical: Lindane is registered for MPB control as a restricted use insecticide. Individual treatment costs vary between $15 & $25/tree. Carbaryl and pine oils are registered as a preventive treatment. Uninfested green tree are sprayed to a height of 25-30 feet. Carbaryl provides protection for two years. Treatment costs for Carbaryl vary between $4 & $10/tree depending upon location.

The use of semio-chemicals to attract MPB and hold this insect within a stand has shown increasing use over the past several years in lodgepole pine. Baits cost $5.50 ea and are employed in grid patterns not over 50 meters between traps. Varying results have been attained and as the techniques and chemical understanding of the beetles improves, their effectiveness and use will no doubt increase.

Where control options are exercised, it is often a mixture of tools that are employed, because the mixture varies between forests and Regions it is not

feasible to break out accomplishments by techniques nor losses adverted to adjacent lands and resource values. Treatment costs charged to FPM have varied between $5 and $375/acre.

TECHNOLOGY INFORMATION

There is considerable technical information for home owners and forest managers available for MPB on risk rating, economic valuation, thinning, preventive sprays and use of pheromones, as well as the proper silvicultural techniques to use to reduce both the short term and long term effects of this insect. What limits its application is the magnitude of host condition in the west and the lack of a necessary marketplace to create the demand for the solution.

In spite of what we know there are several areas where improvements need to be made in our technology. These include:
- the dynamics of MBP in managed stands and host response;
- improvements in semio-chemicals
- the interactions of disease and barkbeetles in managed stands, and their respective response to different management practices.

BARRIERS, AND OBSTACLES

In the application of known technology to the management of MPB, the largest barrier to overcome is the marketplace. The next significant barrier is the resource manager who is unwilling to adapt new or improved technology in managing MPB in a preventive mode. No matter how you view resource management, we simply have an overabundance of mature-overmature forested acres in the west which probably got that way through man's effective fire management programs. Our inability to market this resource in a timely manner prevents us from being very proactive with the biological situation we are in.

As a result of past abuses by man, the conservation movement brought about wiser use of the resources. As the environmental movement gained momentum to its present state of militancy there has been a failure by society to recognize the role forest insects play in the ecosystem. Some of these insects have become pests, such as the MPB. Recognition of their role as ecological agents of change is not recognized as a desirable state except in wilderness ecosystems. Since the MPB knows no boundry, except its' host, it comes to bear in decision making only when it is perceived that it will prevent the attainment of a management objective. On one piece of land it can be recognized as beneficial, and yet another, detrimental. While I know of no policies, regulations or laws that truely act as a limitation on an effective response to the beetle there are concerns that the allocation of land to various "dedicated uses" acts as a barrier to response. However, in the allocation process we could improve our decision making by incorporating MPB upfront.

One not so easily resolved limitation is the ability of minority publics to halt the execution of sound management decisions through the NEPA process.

ANSWERS TO THE NINE QUESTIONS ON THE FUNCTIONING OF PESTS IN THE FOREST ECOSYSTEM.

A. To what extent is aging of the forests related to the incidence of forest pest outbreaks?

Trees become vulnerable to different insect species at different ages. In stands made up of predominently one tree species in one age class there is a large niche for a particular insect to exploit. This situation promotes insect population growth and is evidenced by increasing levels of tree damage. Tree size and growth rate tend to be more important factors involved with MPB outbreaks than tree age though it takes a minimum number of years before a tree attains the minimum size required to create beetle habitat. Other important factors involved in MPB outbreaks are stand density and spacing, the proportion of available host, and the proximity of the host to high beetle populations.

Extensive outbreaks of MPB are less common in mature/overmature ponderosa pine but are found more frequently in the densely growing pole size or second growth stands. This observation emphasizes the importance of size-growth factors rather than age with regards to MPB outbreaks. It also emphasizes the need for stand density and spacing control in the future management of ponderosa and lodgepole pine stands.

B. To what extent do forest plans and the NFS planning process address forest pests and forest health?

Forest plans and the NFS planning process have not addressed forest pests or forest health issues in an effective manner. They cover these issues with broad statements as - '... will be handled on a case by case basis using IPM'. Waiting until a problem arises before dealing with it greatly reduces or prevents the use of <u>integrated</u> pest management. More often than not, by the time an insect situation is recognized as an issue, the population is so large that suppression is the only recourse. Chemical suppression of MPB populations is not effective since the circumstances leading to the outbreak remain unchanged. Integrated pest management includes more than just suppression of a population by various techniques, it includes <u>prevention</u> of the population increase. Prevention is the most effective method of reducing losses from MPB outbreaks. Increasing evidence shows that thinning lodgepole pine stands greatly reduces the incidence of MPB infestation in those stands. The explanation for this reduction is not yet completely understood. Some people believe thinning increases the growth and therefore the vigor of the trees while others believe it changes the microclimate of the stand to the detriment of the infesting beetles.

C. What triggers a decision to take action against a forest pest?

The decision to take action against a forest pest is usually made in response to observing large expanses of dead or dying trees. Public pressure may also play a role in the decision when timber values are not considered important but aesthetics are. Again, this is ususually in response to viewing large areas of red trees. At this point, especially with regards to MPB, the outbreak is already in full swing and it is difficult if not impossible to stem

the losses through integrated pest management. The most effective method of treating MPB outbreaks is to prevent their occurence. Once the outbreak has begun, management is reduced to harvesting stands before the beetles attack it or to salvaging them afterwards. This presents problems in fulfilling management objectives and with current timber markets. If the potential outbreak was recognized early, alternate management strategies could be planned that would still meet the objectives and minimize any negative impacts on the timber marketplace.

D. How does the public's knowledge of forest ecology and forest management influence decisions affecting forest health?

The generally uninformed urban public views the forest as a "static" entity and desires to keep it that way. However, the public's knowledge of forest ecology is increasing as is their interest in forest management often as the result of a MPB outbreak. This has led to some healthy skepticism of Forest Service management practices and resource allocation. Below cost timber sales and increased cutting levels are being viewed as methods of subsidizing the timber industry at the expense of other resources. Clearcut harvesting is viewed with skepticism in some areas. MPB outbreaks occur most often in low value lodgepole pine stands. In an effort to prevent an outbreak it is highly likely that the costs of treatment will be greater than the value of timber removed. It is imperative that clear and open communication between the Forest Service and public exist to prevent suspicion of hidden agendas and the blockage of timely treatments. The public is becoming increasingly sophisticated in their knowledge of forest ecology and forest management, and these facts should be reflected in Forest Service information and education programs. Insect impacts should be described in terms of their ecological impacts and not strictly in terms of timber values. Describing a MPB outbreak in terms of elk cover and hiding loss and an increased threat of wildfire will have a greater impact than describing it in timber volume lost. Treatments to prevent MPB outbreaks can increase the diversity of the area and enhance wildlife hbitat, especially for big game. In some areas this may be a better management objective than managing for timber.

E. To what extent does the technology exist for enhancing and maintaining forest health?

The technology to enhance and maintain forest health currently exists. The problem isn't the lack of technology but in confusing biological management with politics, economics and planning. MPB outbreaks can be averted through intensive management but this type of management is not politically or economically astute in most cases. More information on levels of thinning, timing of treatments, and the economic potential of managed pine stands would be helpful to refine the existing level of knowledge at the habitat level.

F. How have man-caused changes in natural dynamics of the forest ecosystem influencing fire activity ecosystem diversity, and nutrient cycling affected the incidence of pest outbreaks?

Man-caused changes in the forest ecosystem have increased the potential for insect outbreaks. They have done this through harvesting and fire

suppression. Harvesting large or adjacent areas and replanting to single species has created large areas of single age, single species stands. This practice has greatly reduced the diversity of the ecosystem and therefore its stability. When the stand becomes susceptible to an insect species there is a large habitat to exploit and extensive damage results. Lodgepole pine communities are generally maintained by fire. The effects of maintaining single age, single species stands are vividly shown in any MPB outbreak. In this case, management can be used to increase the stand diversity and reduce the potential for outbreaks.

Fire exclusion in ponderosa pine habitats in the West has allowed the encroachment of Douglas-fir in the understory. This increases the density of the stand and increases the susceptibility of ponderosa pine to MPB and in some areas, western pine beetle. In addition, since the habitat is marginal for growing Douglas-fir it also is susceptible to other insects such as western spruce budworm.

We hear a lot about fire protection increasing the amount of susceptible type. However, it's a two-sided coin. With fire protection, succession has progressed to eliminate lodgepole in many stands now dominated by spruce and fir. Fire protection has probably resulted in more acres of similar age and consequently more acres susceptible to beetle damage at one time. Had more fires been left to burn, a greater diversity in tree age and size class probably would exist today and the pest problem would be less extensive at any one time but nevertheless continuous as trees reach sizes conducive to MPB.

g. and h. One perception is that dealing with forest health is made more difficult by public involvement, but we can't leave the public out. We need to do a better job of educating them. In some cases where technology existed to mitigate effects, public involvement prevented it. An example is campgrounds at McGregor Lake, Lolo NF. The use of protective sprays was opposed by the public. As a result, most trees were killed by MPB and residual trees had to be removed to prevent blowdown on campers, leaving no trees for shade and screening.

At the other end of the spectrum, public knowledge of forest ecology has been instrumental in developing and supporting forest management practices in Colorado to prevent continued tree loss by MPB. It is important to keep in perspective that in nature, there are no rewards nor punishments, wins nor losses, but only consequences. The interpretation of these consequences, the value judgements by man, then make up the essence of forest health which will constantly vary in time and space and be interpreted with as much variability.

i. At the present time, we do not see a relationship between MPB and land ownership. However, in the future, as intensive management increases, unregulated forest land will provide refugia for some of our pests, that will provide sources of infestation to adjacent managed stands.

DWARF MISTLETOES IN WESTERN FORESTS

David W. Johnson

Ecosystems And Geographic Area Covered In This Analysis: Practically all members of the pine family in the western United States, including the pines, true firs, spruces, Douglas-fir, larch and hemlock, are parasitized by members of the genus Arceuthobium. Fifteen species of dwarf mistletoes occur in the West. The commercially important principal hosts, mistletoe species, and their general distribution are listed in table 1. The southern and eastern pine forests are not affected; cedars, cypress, junipers, redwood, and giant sequoia are immune.

Background And Current Situation: The status of dwarf mistletoes does not change markedly from year to year. Mistletoes spread slowly, at a rate that averages one to two feet per year in even-aged stands. The rate of spread is balanced by timber management activities and direct suppression, which reduce the acreage infested each year. Recent estimates are that more than 22 million acres of commercial forest land is infested resulting in annual losses in growth and mortality at 382 million cubic feet (table 2). Volume losses reported are only for commercial forest lands and includes both growth loss and mortality. These estimates are conservative. Not all forest land and classes of ownerships are included: the figures for Arizona, Colorado, New Mexico, and eastern Wyoming include only National Forest lands. The total growth loss and unsalvaged mortality from all insects and diseases averages 5 billion cubic feet per year; dwarf mistletoes therefore cause about 8 percent of the total growth loss and mortality nationwide.

The most important effect of dwarf mistletoes is volume reduction; when trees are heavily infested, dwarf mistletoes reduce both height and diameter growth and increase mortality. In some hosts, for example, Douglas-fir, western larch, and southwestern ponderosa pine, mortality losses exceed those from growth reduction. The extent of loss depends upon several factors including host and mistletoe species, intensity of

infection, site index, and stand density. Infestation levels vary greatly from stand to stand dependent primarily upon fire history of the stand and past management practices. Significant reduction in yields of stands occurs if they are infected early in their development and if no suppression measures are taken to reduce the spread and intensity of the disease.

The first symptom of infection on an individual tree is a swelling of host tissues. Later the swellings enlarge and produce dense masses of distorted branches called witches' brooms. As the parasite spreads through the tree crown, tree growth is gradually reduced. Eventually the top weakens and dies, diameter growth ceases, and the entire tree dies. Insects, particularly bark beetles, may cause an earlier death by attacking weakened trees. Other pests, such as decay fungi, enter wounds and swellings created by the mistletoes.

Mistletoes not only reduce growth and cause mortality of affected trees, but adversely affect recreation values by killing trees in recreation sites. In addition, the decay and canker fungi associated with dwarf mistletoe infections kill or weaken branches so that they are more susceptible to wind breakage, thus increasing the hazard to recreationists.

Although the debilitating effects of the mistletoes on tree growth and forest productivity are well documented, their effects on non-commodity forest values have not been fully assessed. The effects on wildlife, for example, may be positive or negative, depending upon the particular ecological needs of the wildlife species. Dead trees provide nesting sites for snag dependent bird species. Witches' brooms also provide cover and nesting sites for many birds and mammals. Large areas infested with mistletoes have a more irregular, open forest canopy, favoring certain bird and mammal species. As these openings regenerate to either the same tree species or other tree species and brush, greater vegetation diversity will occur. This results in profound changes in both stand structure and species composition. The mistletoe plants themselves provide a food source for some mammals, birds and insects.

The impacts of dwarf mistletoes on visual quality would generally be considered negative through reduced tree vigor, increased mortality, and increased fuel accumulations and susceptibility to fire. Effects on other resource values are, for the most part, unavailable.

About 25 million years ago, the dwarf mistletoes and western conifers began evolving together. Today, the dwarf mistletoes are one of the most widespread and damaging groups of forest diseases in the West. Large fires also played a role in shaping these forests. Fires changed forest composition and sanitized infested stands by killing the parasite when the host tree was killed. The new, replacement forests were essentially free of mistletoes where large fires occurred.

Control Responses: Silvicultural practices to control dwarf mistletoes have been advocated since the early part of the century; however, these efforts were limited to removing only the most seriously infected overstory trees during the course of logging operations. This type of partial

cutting actually increased the amount of infection in residual stands. Leaving infected trees of no commercial value in regeneration areas also intensified the problem.

Forest roads and timber markets began improving in the 1950's. Improved access and markets, coupled with more specific guidelines from research, made it possible for managers to take more effective action against the dwarf mistletoes.

In the past decade or so, dwarf mistletoe control programs have been more consistent. In addition, thousands of acres are treated each year through scheduled stand improvement and timber harvesting operations. Current control programs vary slightly from year to year. Table 3 summarizes the Forest Pest Management funded suppression program for each of the western Regions for the last 5 years. More than 1 millon acres have been surveyed and 91,000 acres treated at a cost over $6 millon with FPM funds. The range in costs for each Region for the various treatments are presented in table 4.

In many cases direct control costs for dwarf mistletoe suppression are difficult to quantify as costs depend to a large extent on the sizes and numbers of infected trees per acre. Treatments are often combined with regularly scheduled stand entries rather than as separate treatments.

Treatment Options: The dwarf mistletoes are most easily and economically treated by silvicultural practices. Several features of these parasites make them ideal candidates for cultural management.

- Dwarf mistletoes require a living host to survive. Once an infected tree or branch is cut, the mistletoe dies. There is no need to destroy the slash.

- Mistletoes are generally host specific; that is they are usually confined to a single host species or group of closely related species, as indicated in table 1. Immune or lightly infested species can be favored during stand treatments.

- Dwarf mistletoes spread slowly. Seed dispersal from a tall, isolated tree is usually limited to less than 60 feet. In even-aged stands, spread is even more limited, averaging 1 to 2 feet per year.

- Dwarf mistletoes have a long life cycle: mature plants take 4 to 6 years to develop from seeds. From a practical standpoint, this long life cycle means the amount of inoculum builds slowly. If a stand is properly treated, mistletoe should not be a serious problem in subsequent rotations.

- Infected trees and stands are easy to detect because of the presence of dwarf mistletoe plants, branch and stem swellings, and witches' brooms. Heavily infested stands show decline and mortality.

Successful silvicultural techniques have been developed specifically for dwarf mistletoe control. These practices can be easily integrated into planned harvesting and intermediate stand treatments. These strategies are aimed at either prevention or suppression of the disease dependent upon the

age of the stand and management objectives. Because it is much more effective to prevent mistletoes from becoming established than to eradicate them from infested stands or replace severely infested stands, the priorities in control programs should be placed on prevention. Prevention can be accomplished by:

- Designing treatment units to take advantage of natural or manmade barriers (such as roads, streams, non-susceptible forests, openings, or meadows) that prevent reinvasion from adjacent infested stands.

- Felling or girdling all infected trees before an area is planted or naturally regenerated.

- Using clearcuts when harvesting infested stands. Long, narrow cut strips should be avoided.

- Regenerating stands with the shelterwood method leaving mistletoe-free or lightly infected residual trees. If infected trees must be retained (for instance, in areas sensitive to visual quality objectives or protection of the site from adverse microsite conditions), they should be removed as soon as the site has regenerated and before the regeneration is 3 feet tall or 10 years old.

- Favoring non-susceptible tree species when regenerating a stand or making intermediate entries.

These strategies all reduce the likelihood of dwarf mistletoe spreading into a healthy stand. When a stand is already infested, all infected overstory and then selected infected understory trees can be felled. This technique, known as sanitation-thinning, can be applied in lightly infested stands. Crop trees should be disease-free. However, lightly infected trees may be retained to meet minimum stocking guides. Replacing severely infested stands with healthy stands by clearcutting, roller chopping, or prescribed burning and regenerating may be recommended for heavily infested stands.

In developed sites and recreation areas, the emphasis of control programs has been to reduce spread from individual infected trees and prolong the life of trees by pruning infected branches. Non-susceptible tree species may be planted in the understory with the eventual removal of infected overstory trees.

What measures or combination of measures are used should depend upon individual stand conditions including stand age and composition, stand density, number of years to harvest, mistletoe incidence and distribution, and length of time the stand has been infested. Valuable tools-- tree and stand growth models and dwarf mistletoe infection models-- are available to aid the resource manager in simulating yields of infected trees and stands. Yields for a stand can be predicted under various management regimes and compared to no treatment. By comparing outputs and economic analyses of control costs, the manager can choose the best treatment for each infested stand and priority for entry.

Technology Information: Current silvicultural strategies are more than adequate to prevent and reduce infection of regenerated stands. The treatment of old growth infested stands should be delayed until harvest. Additional research is needed to incorporate existing dwarf mistletoe loss and intensification data for lodgepole pine, ponderosa pine, Douglas-fir and western larch into the growth and yield model PROGNOSIS for Regions 1, 4, 5, and 6. In addition, loss and intensification data are needed for the southwestern mixed conifer and unevenaged ponderosa pine submodels of the growth and yield simulation model GENGYM being developed by the Rocky Mountain Station. All dwarf mistletoe and stand models need to be validated and updated periodically as new information becomes available.

Additional areas that need research include: quantification of intensification rates and effects of dwarf mistletoes in managed Douglas-fir, western larch, ponderosa pine and lodgepole pine stands; impact of western hemlock dwarf mistletoe in Alaska versus Oregon and Washington; possibility of use of biological and chemical controls in high value stands and recreation sites; interactions of dwarf mistletoes with bark beetles, other insects and diseases; and the effects of dwarf mistletoes on resource values other than timber.

Obstacles and limitations to the implementation of existing technology include the following:

- A repeated history of selective harvesting in dwarf mistletoe infested stands, particularly in southwestern ponderosa pine and mixed conifer stands.

- The perpetuation of unevenaged stand conditions that accentuate the spread of dwarf mistletoe from overstory to understory trees.

- Incomplete removal of infected trees, usually non-merchantable trees, left standing in timber sale areas.

- Retention of infected trees along visual corridors and subsequent spread to adjacent uninfested stands.

- Limitations on the size of clearcut units. It is most effective to clearcut infested stands at least 20 acres in extent to minimize reinfection from the edges of the stand. Small clearcut units can aggravate and intensify the rate of infection.

- Lack of training in forest pathology and silviculture of young graduate foresters. Knowledge of incorporating disease control information into routine forest management prescriptions is particularly needed. (That is avoiding pest problems rather than waiting until they attain epidemic status).

- Forest Plan harvest levels are not great enough to regenerate old growth, heavily infested forests.

- Lack of detailed action plans prioritizing stands needing treatment.

Response To Specific Questions:

a. To what extent is aging of the forests related to the incidence of forest pest outbreaks? Dwarf mistletoes intensify slowly over time. The dwarf mistletoe rating of a stand (DMR) increases one increment, for instance from an average DMR of 2.0 to 3.0, in 15-20 years. Once a stand reaches an average rating of 3.0 or greater, significant growth reduction and mortality occurs. A stand can reach a maximum rating of 6.0, if infected at an early age, before maturity. The mistletoe will prevent the stand from reaching a suitable size and diameter for harvest. Severely infested stands have no merchantable value other than for fuelwood. Infested stands adjacent to regenerated, disease-free stands can result in infection of younger stands along the borders. Dwarf mistletoe seed can be dispersed up to 60 feet from the infested edge trees into regenerated areas. Delayed conversion of heavily infested stands has produced large increases in loss, whereas regeneration harvests could convert these stands back into productive forests.

b. To what extent do forest plans and the NFS planning process address forest pests and forest health? In most cases not adequately. The first forest plans were written with poor inventory data and have not involved Forest Pest Management specialists to the degree that is needed to address these issues. Many of the major forest insects were discussed in the plans, but most forest diseases, including the dwarf mistletoes, are not adequately covered. We need to strive to be more involved in the planning process in the next sequence of plan preparation.

c. What triggers a decision to take action against a forest pest? The process exists whereby Forest Pest Management specialists should be consulted when a question arises concerning the need for a control project. After a biological evaluation and economic analysis have been completed, a decision can be made as to the worth of a particular project. Because of the slow rate of spread of mistletoes, it is possible to formulate projects 5-10 years in advance and program activities into the scheduled timber sale program. More emphasis needs to be placed on this approach to dwarf mistletoe suppression.

d. How does the public's knowledge of forest ecology and forest management influence decisions affecting forest health? The lack of knowledge of these subjects and misunderstanding of our forest practices has put us into court in the past. We need to do a better job of public information and involvement in the future. Where local publics are knowledgeable, we have no problem getting support for pest control projects. In most cases, dwarf mistletoe projects in old timber sale areas and recreation sites have little or no impact, thus there is no adverse opinion.

e. To what extent does the technology exist for enhancing and maintaining forest health? Sufficient information exists currently to manage the forest resource and reduce the impacts by mistletoes, the problem lies in the lack of markets locally for forest products, restrictions on harvests, and litigation involving forest practices.

f. How have man-caused changes in natural dynamics of the forest ecosystem influencing fire activity, ecosystem diversity, and nutrient cycling affected the incidence of pest outbreaks? The reduction in number and size of wildfires has prevented the regeneration of heavily infested old growth forests and the subsequent formation of vast areas of mistletoe-free stands. Past harvesting practices, particularly partial cutting, high-grading, etc., has aggravated the spread of the disease in infested stands and resulted in high levels of infection of understory regeneration.

g. How has the increased public involvement in the forest management decision-making process affected forest health? The major impact has been on limiting the amount and size of clearcuts. In heavily infested old growth forests, clearcutting is, for most purposes, the most economic and effective means of creating dwarf mistletoe-free stands. Where mixed tree species are present, immune or less susceptible species can be retained; however, in the vast lodgepole pine and ponderosa pine forests in the West, clearcutting is the only alternative.

h. How have public perceptions about pest-caused damages, losses, value of losses, cost of treatment or prevention, and risks of treatment affected forest health? For the most part, the general public is unaware of these issues, particularly dwarf mistletoes. Where an informed public is present, we usually get requests on how to control the disease in high value trees. Responses are favorable to do something.

i. Do the frequency and intensity of outbreaks by this pest vary by land ownership? What factors explain this difference? Although no specific data is available on incidence of mistletoes by ownership pattern, I would expect more of the small private land holdings, where the disease occurs, to be heavily infested. The lack of harvesting, control of fires, and partial cutting aggravate spread and intensification of the disease. Also this class of landowners would be less informed on the biology of dwarf mistletoes and management practices available to suppress the disease.

Recommendations:

Further analysis updated: For the most part, the general distribution and hosts of the western dwarf mistletoes are known. Specific information on the location and intensity of the disease is needed, however, for each stand in order to program suppression efforts. This information can be obtained through forest inventory or presuppression surveys.

Added information needed: Growth and yield programs are available for some western dwarf mistletoes; even-aged lodgepole pine in the central Rocky Mountains and even-aged and two-storied ponderosa pine in the central Rocky Mountains and the Southwest. Models are being developed for mixed conifers in the Southwest, uneven-aged ponderosa pine for Colorado and the Southwest, and for all important conifers in the Pacific Northwest and Northern Rockies. Research on the effects of mistletoes on non-commodity

forest values is needed for more complete economic analyses of proposed projects. Research should continue on promising biological and chemical controls for use in high value forests and recreation sites. Alternatives to silvicultural treatment are needed.

Actions needed now: Reduction of losses to the mistletoes is most effectively and efficiently achieved through good silvicultural practices and the integration of control programs into planned stand entries and harvests. Long term planning that is incorporated into timber sales is needed for control programs to be successful. Infested stands should be prioritized and scheduled for treatment. Monitoring of treated stands is necessary to insure the applied treatments are effective. Timber contracts should stipulate felling of all non-merchantable infected trees in harvest units. Some Regions report the need for more staffing to manage and monitor suppression programs and perform service trips and reviews.

Actions needed within 5 years: With the current knowledge available on the biology and management of dwarf mistletoes, the greatest need in the near future is the continued implementation of control projects in a systematic manner. Continued budget support of dwarf mistletoe projects is needed to treat infested stands. In the meantime, there should be a shift from reliance on FPM funds to complete suppression projects to accomplishment of these same objectives within the timber program. It would be helpful if the Regions were assigned targets (acres surveyed and treated) and funds to complete the needed work. Forest Pest Management specialists should participate to a greater degree in interdisciplinary teams assigned to timber sales, recreation site developments and expansion, and other vegetation management projects. They also need to play a more important role in forest planning. Continuing emphasis must be placed on training foresters involved in inventory, sale layout, and tree marking to insure that silvicultural prescriptions include dwarf mistletoe suppression. In Region 2 and some other western Regions, these actions alone are not sufficient to accomplish these objectives without increased demand for forest products, increased harvesting activity and conversion of infested stands to disease-free stands.

Table 1. Commercially important tree species in the western United States that are principal hosts of dwarf mistletoes.

Important principal hosts	Distribution	Dwarf mistletoe (common name)
Douglas-fir mistletoe	Arizona,California,Colorado Idaho,Montana,New Mexico, Oregon,Utah,Wyoming	Douglas-fir dwarf
Western hemlock	Alaska,Oregon,Washington	Hemlock dwarf mistletoe
Western larch	Idaho,Montana,Oregon Washington	Larch dwarf mistletoe
Lodgepole pine	California,Colorado,Idaho Montana,Oregon,Utah, Washington,Wyoming	Lodgepole pine dwarf mistletoe
Red fir	California,Oregon	Red fir dwarf mistletoe
Ponderosa pine mistletoe	Arizona,Colorado,New Mexico,Utah	Southwestern dwarf
Ponderosa pine	California,Idaho,Oregon, Washington	Western dwarf mistletoe
Jeffrey pine	California,Oregon	Western dwarf mistletoe
Sugar pine	California,Oregon	Sugar pine dwarf mistletoe
White fir	California,Oregon	White fir dwarf mistletoe

Table 2. Acres infested and average annual losses caused by dwarf mistletoes.

State	Acres infested	Cubic feet lost
Alaska	1,500,000	11,000,000
Arizona*	1,040,000	8,140,000
California	2,200,000	120,000,000
Colorado*	638,000	5,800,000
Idaho	3,224,000	42,280,000
Montana	2,416,000	33,250,000
Nevada	62,000	580,000
New Mexico*	1,140,000	16,570,000
Oregon	4,885,000	76,560,000
Utah	461,000	4,750,000
Washington	3,575,000	55,440,000
Wyoming*	637,000	8,250,000
Totals	21,778,000	382,620,000

*National Forest lands only.

Table 3. Dwarf mistletoe accomplishments in the Forest Service western Regions (1983-87)*.

Region	Acres surveyed	Acres treated	Total cost
1	28,300	5,700	442,000
2	112,500	24,100	2,028,200
3	274,600	27,000	616,200
4	667,200	23,300	1,866,300
5	3,700	1,000	372,200
6	23,600	9,900	769,200
10	0	0	0
Totals	1,109,900	91,000	6,094,100

*Accomplishments with FPM funds only.

Table 4. Dwarf mistletoe control costs (dollars) per acre listed by treatment and Forest Service Region.

Region	Presuppression survey	Residual felling	Sanitation-thinning	Stand destruction	Pruning
1	2.25-4.60	40-60	-	-	-
2	2.00-5.00	50-100	50-150	50-70	-
3	4.00	-	45-150	-	20-60a
4	0.55-1.00	47-72	-	-	-
5b	3.75-12.00	200	90-1460c	-	100-200
6	1.00-6.00	48-80	72-150	134-215	85
10	-	15-20	-	-	-

a Costs per tree.
b Region 5's high per acre costs are primarily due to individual tree treatments in developed recreation sites.
c Includes combination treatments of sanitation thinning and pruning.

DOUGLAS-FIR TUSSOCK MOTH

Jerald E. Dewey

Douglas-fir tussock moth, Orgyia pseudotsugata (McD.)

The Douglas-fir tussock moth is a foliage-feeding insect that frequently causes damage to interior conifer forests in the United States and Canada. This insect is characterized by extreme population fluctuations. When populations are high, damage to its host can be extreme.

Distribution

The Douglas-fir tussock moth is found throughout the range of Douglas-fir, grand fir, and white fir. It has been collected from parts of British Columbia, Washington, Oregon, Idaho, Montana, California, Nevada, Utah, Colorado, Arizona, and New Mexico. Although it is commonly found west of the Cascade Range, to date no major outbreaks have occurred in the coastal variety of Douglas-fir. It is also not abundant east of the Continental Divide. All of the known major outbreaks have occurred in the Sierra Nevada Range in California and from the Blue Mountains in eastern Oregon north through eastern Washington and northern Idaho and into British Columbia.

Preferred Hosts

The major tree species affected by the Douglas-fir tussock moth are Douglas-fir, grand fir, and white fir. Subalpine fir is a minor host species.

Douglas-fir

Douglas-fir is one of the most valuable timber species in North America. It grows in all 11 western States plus Texas and the two western provinces of Canada. The coastal variety is found west of the Cascade Range in Washington and Oregon, west of the Coast Range in British Columbia, and west of the Sierra Nevada Range in northern California. The Rocky Mountain variety occurs in southwestern Alberta, central and southern British Columbia, Montana, Idaho, eastern Washington and Oregon, Wyoming, Colorado, and the southern mountains of Utah and eastern Nevada, Arizona, New Mexico, and western Texas.

Coastal Douglas-fir grow in mild and humid regions with dry summers. Rocky Mountain Douglas-fir prefer the subhumid zones in the generally more severe climates to the east where annual precipitation is much less. Along the coast Douglas-fir grows from sea level up to about 6,000 feet in the southern part of its range. In the northern portion it may reach 8,000 feet. The Douglas-fir zone lies above the ponderosa pine and below Engelmann spruce/subalpine fir zone. In the warmer and drier portions of its range, Douglas-fir is confined to north-facing slopes and shaded areas. At high elevations, it grows on sunny exposures and not on the cooler sites.

Douglas-fir is generally rated as a good seeder. Germination occurs on almost any seedbed that provides adequate moisture and proper temperature. Shade aids early growth but, once estasblished, seedlings grow best in full sunlight. Natural thinning begins early in dense Douglas-fir stands as suppressed trees are shaded out and die. Douglas-fir maintains a fairly rapid height growth rate over a long period of years. Mature stands can yield 50,000 fbm per acre, with trees as large as 50 inches in diameter and over 150 feet tall. In the Southwest, these figures would be somewhat less. Douglas-fir has intermediate shade tolerance and occurs both as a seral and climax species.

Grand Fir

Grand fir grows in the stream bottoms, valleys, and mountain slopes of western Washington, Oregon, and northwestern California, and also in Idaho and western Montana, and extends well into British Columbia.

Grand fir does very well on both deep, well-drained alluvial soils and thinner exposed soils of ridges. It is predominantly a lowland species, but reaches 6,000 feet in the Inland Empire of northern Idaho where the best stands are found. Grand fir is moderately tolerant but less so than many associates. It is short lived, usually maturing in 90 to 120 years. It is also very sensitive to drought and sulfur dioxide.

Grand fir begins seed production at about age 20, but most crops are light. Germination is seldom better than 50 percent. Initial survival and growth of grand fir are favored by moderate shade. In Idaho early annual height growth is 12 to 24 inches on the better sites. As an understory tree, it usually outgrows western hemlock and western redcedar. Grand fir can reach over 200 feet in height and 50 inches in diameter. In the inland regions of the Northwest, grand fir is second only to western white pine as a high-yielding species. At 120 years, grand fir can produce over 60,000 fbm per acre. It is the climax species on many sites that are too dry for western hemlock or western redcedar.

White Fir

White fir is widely distributed in the Rocky Mountain and Pacific Coast regions, extending from New Mexico and Wyoming westward to Oregon and California. It attains its best development in California and southwestern Oregon. It is the principal tussock moth host in Arizona, California, Nevada, and New Mexico. White fir does very well in cool, moist situations and in the higher mountain areas where winters are long and snow deposits are moderate to heavy. Growth is rapid up to about 100 years, then slows quickly. White fir is subject to windthrow and storm breakage.

Cone production varies, but good crops occur at 3- to 9-year intervals. Good crops are more abundant during its period of early, rapid growth. Germination is usually not more than 50 percent and occurs over heavy litter conditions. In the Southwest, spring drought often hampers seedling development. Growth is usually very slow up to about age 30, then growth accelerates markedly. On the best sites, white fir can reach 140 to 180 feet tall and 40 to 60 inches in diameter. Fully stocked 100-year-old stands in California can yield 74,000 fbm per acre on average sites and over 147,000 fbm on the best sites. White fir is rated from tolerant to very tolerant of shade throughout its entire life.

Area Occupied by Host

Acres of commercial timberlands (thousands of acres)

Species	Forest Service	Other public	Forest industry	Small private	Total
Douglas-fir	14,392.3	5,293.6	4,956.5	6,254.8	30,897.2
Grand/white fir	13,521.8	1,185.6	1,510.3	2,108.3	18,326.0

Outbreak Cycles and Triggers

Douglas-fir tussock moth outbreaks have occurred many times since surveys and record keeping began early this century. Most of the time, population numbers are relatively stable at very low densities. During this endemic period, larval feeding goes unnoticed and all life stages are difficult to find except for adults collected in pheromone-baited traps. As the first phase of an outbreak begins, population numbers increase dramatically. This rapid buildup is most often accompanied by heavy to severe defoliation. Just as the population reaches its peak, it takes an equally dramatic population collapse. A native virus disease is usually the primary cause of this decline. The entire outbreak phase typically lasts 3 to 4 years and tends to repeat itself every 8 to 10 years. Historical records show this cyclic pattern began in the early 1930's. Second to British Columbia, the Pacific Northwest has had the most consistent and longest outbreak pattern. In other areas, the pattern tends to be a little more irregular, but the extremely large population buildups followed by longer periods of very low populations are characteristic of all areas. Even though tussock moth outbreaks have a fairly consistent pattern, no single factor has been found that marks the beginning of each outbreak. Spring and summer temperatures, drought, genetic composition of the population, and other factors have all been discounted as a common cause.

Attack Behavior/Damage

Douglas-fir tussock moth feeds on the foliage of several conifer species. It completes its life cycle within 1 year and passes through four stages: egg, larva, pupa, and adult. Eggs are deposited in a mass on the outer surface of the female cocoon. The young larvae emerge from the eggs during early June and move to the current year foliage. New foliage is the preferred food, but when it is gone, latter-stage larvae feed on the old foliage. Tussock moth larvae go through five to seven stages depending upon sex and environmental conditions. In late July and August the mature larvae spin cocoons and pupate. About 15 days later the adult moths emerge. The wingless female lays its eggs on its cocoon.

Foliage destruction is the primary cause of tree damage. Depending on population density, defoliation can cause diameter and height growth reduction, top kill, and tree mortality. Trees that are not killed but only weakened are then much more susceptible to bark beetle attack or other secondary agents. As trees die from defoliation or later from secondary agents, stands not only have a direct loss in tree volume per acre and its associated timber value, but other resources are also affected. These impacts can affect fire hazard, regeneration and stand management, recreation, and wildlife. The end result can be stands with greatly reduced resource values and potential. To meet resource

needs and targets, it is necessary for managers to reallocate resources and modify management plans.

Current Situation

Status of Outbreak

Currently there are three low intensity outbreaks of Douglas-fir tussock moth. The largest is located between Moscow and St. Maries, Idaho, where over 500,000 acres are infested. Another outbreak is an area of about 1,000 acres in northern California on the El Dorado National Forest near Placerville. The third is a newly discovered outbreak of about 2,000 acres on the Plumas National Forest near Quincy, California.

Ownership in the northern Idaho outbreak area includes Forest Service, Indian Reservation, industry, and small private lands. This outbreak was first detected in 1981 using pheromone-baited traps. By 1982, over 500,000 acres were infested at a very low level. This represents about 1.5 percent of the host type. Trap counts increased each year until 1986 when counts declined. Without the use of pheromone traps, this outbreak would probably have been overlooked until 1986 when nearly 2,000 acres of aerially visible defoliation were recorded. Larval population density in 1986 declined in most areas. Overall, the population density of small larvae in 1987 declined based on lower and midcrown samples collected in June. This coincides with the lower trap counts in 1986. The highest larval populations in June were in those areas defoliated in 1986. The density in a few of these may be high enough to cause visible defoliation in 1987. But as the outbreak continues to decline, by 1988 most evidence of this outbreak should be gone, and by 1990 pheromone trap counts should be back to the pre-1981 levels.

The northern El Dorado outbreak was first detected by increased pheromone trap counts in 1984. A 50-acre area of visible defoliation was found in 1985. Trap counts in 1986 were near the 1985 level. No visible defoliation occurred in 1986. This outbreak should subside in 1987.

The outbreak on the Plumas NF was just detected this summer (1987). Surveys have not been completed to provide trend information. Patches of heavy defoliation are clearly visible and cocoons and egg masses are conspicuous.

Besides a now inactive outbreak in northeastern Washington and small localized outbreaks in New Mexico and Colorado, no other significant tussock moth activity has occurred since the collapse of the last cycle in 1975. Although the population density recorded during the Washington outbreak was well below densities recorded in the past, the release, buildup, and decline phases were characteristic of past outbreaks. Population buildup didn't occur in many of the traditional infestation areas, and where increased activity did occur, it was at a very low level. Even so, we must acknowledge that the timing of current activity matches the expected outbreak cycle. If this frequency continues, the next outbreak should begin sometime near the mid-1990's. Most previous outbreaks resulted in major forest impacts. Forecasts of impacts caused by future outbreaks may now be less reliable than in the past.

Outbreak Cause

The underlying cause of DFTM outbreaks is a susceptible forest. This is largely the result of many years of forest management with fire prevention emphasized.

Other management practices have also encouraged a gradual shift from seral species to increased areas of climax species. This change in stand composition has resulted in large areas with tree species which are more subject to DFTM outbreaks. As stands become more susceptible to the tussock moth, an apparent 8- to 10-year outbreak cycle has developed. This cycle is controlled by many environmental factors of which the naturally occurring virus is probably the most important. In the years since the 1970's outbreak, forest managers have done much to break up large areas of susceptible host via timber sales. This might contribute to the intensity of the current outbreak being much less than expected.

Impacts

Impacts from the most current outbreak were minimal in that only a few thousand acres exhibited visible defoliation for a single year. As such, the impacts described here are taken from the 1970's outbreak, which is more typical of recent outbreaks.

Extensive damage occurred on about 800,000 acres within 3 years in Oregon, Washington, and Idaho following the 1970's tussock moth outbreak. Additional damage occurred from relatively small, somewhat localized outbreaks in California, Montana, Colorado, and New Mexico during this same time period.

The primary impact of a tussock moth outbreak is on the timber resource. However, losses can occur associated with recreation, fire presuppression, residential and recreational land values, and costs of reforesting immature stands. Some benefit can be derived from a gain in grazing values, and perhaps an increase in wildlife forage.

The timber resource is impacted by (1) mortality of mature timber, (2) growth loss to mature and immature timber, and (3) loss of immature timber as growing stock.

After accounting for the value of dead trees that were salvageable, the total projected loss to all resources for the Oregon, Washington, and Idaho 1970's outbreak was projected at approximately $70 million or $107.50 per acre.

Control Response

During 1986, 33,000 acres in northern Idaho were scheduled for treatment with the Douglas-fir tussock moth nucleopolyhedrosis virus (NPV). Larval populations did not reach the expected level and as a result only 1,930 acres were treated. Ground surveys and pheromone trap data identified approximately 97,000 acres where defoliation was expected to occur in 1986. Prespray sampling, however, showed the population did not increase as projected. A further population decline was recorded in 1987.

Application cost for the proposed 1986 project was $1.99 per acre with fixed-wing aircraft. The virus was produced and provided by the Forest Service in Corvallis, Oregon. The remaining tank mix ingredients were molasses and orzan (cost included in application).

No other operational control was scheduled during this outbreak.

In 1974, over 425,000 acres were aerially sprayed with insecticide in Oregon, Washington, and Idaho to suppress the outbreak. Of this total, approximately

420,000 acres were treated with DDT. The remaining 5,000 acres were treated with Dylox, Sevin-4-Oil, and a number of other chemical and microbial insecticides.

DDT spraying was the only alternative available for responding to the 1970's outbreak. Because 1974 was the third year of the outbreak in most areas sprayed, it is quite likely that impacts would have been further reduced had spraying been initiated earlier.

It has been estimated that the 1974 spray project prevented an additional loss of 411 million board feet of timber with a value of $11.6 million after subtracting salvage values. In addition, treatment of these areas prevented a loss of $23.8 million in damage to immature trees, growth loss, reforestation expense, recreation loss, and increased fire protection costs. The calculated benefit/cost ratio for this project was estimated to be about 26:1.

Prior to 1974, knowledge and technology were not available to preclude the outbreak. Since then, largely as a result of the Douglas-fir Tussock Moth Accelerated R&D Program, we have a much better understanding of what is necessary for an outbreak to occur. Since 1974, a DFTM/stand hazard rating system has been developed. Some land managers have made considerable progress at reducing stand susceptibility by modifying conditions silviculturally. Also, much has been learned of how to suppress outbreaks using the naturally occurring nucleopolyhedrosis virus and chemical insecticides. Three chemical and two microbial insecticides have been registered for DFTM control since the 1974 outbreak. The Forest Service has now produced and stockpiled a large amount of the NPV for future suppression projects. The intent of the planned 1986 DFTM spray project was to treat a new infestation in its early stages with the virus, suppressing the immediate population and perhaps initiating an epizootic in surrounding untreated stands.

Treatment Options

There are more treatment options available for the Douglas-fir tussock moth than for most forest insects. In addition to silvicultural approaches (e.g., species conversion, stocking density controls, etc.), there are both chemical and microbial insecticides registered for this pest. The registered chemical insecticides are carbaryl, acephate, and the insect growth regulator diflubenzuron. The microbials are the bacteria Bacillus thuringiensis (Bt) and the host-specific nucleopolyhedrosis virus.

Silvicultural management is an on-going effort. DFTM is considered in the silvicultural prescriptions on those Forests with a tussock moth history. Where feasible, prescriptions are selected that have a preventive or ameliorating effect on potential DFTM outbreaks. Costs of these activities are a part of the timber management program.

There has not been a DFTM outbreak of sufficient magnitude since the above-mentioned insecticides have been registered to require their use. Hence, to date there is no "frequency of use" or " accomplishment" or "acres treated by year," etc., data on these materials.

An outbreak was predicted to occur in northern Idaho in 1986. Plans were developed to spray approximately 30,000 acres with the nucleopolyhedrosis virus. The cost of this treatment would have been approximately $12/acre,

assuming a value of $10/acre equivalent for the NPV. The calculated benefit/cost ratio was 2.75:1.

It was suspected that treatment of 30,000 acres would be early enough in the outbreak cycle to prevent a much larger expansion of the outbreak. Besides the 30,000 acres that were to have been sprayed, protection of another 100,000+ acres was expected.

The predicted outbreak did not materialize, thus the project was cancelled.

Technology Information

The state of the technology for preventing and/or reducing the impact associated with DFTM outbreaks is quite good. The primary weakness is that most of this technology is quite new and has never been tried on a large-scale, intense outbreak. Much validation work remains to be done.

An additional technique that is partially developed and could have much application is the tussock moth pheromone as a tool for suppressing or manipulating populations. This material could be an effective means of preventing low-level populations from reaching outbreak levels, or it could be used as a suppression agent.

Additional Information

1. Obstacles to the use of existing technology: The infrequency of DFTM outbreaks is the biggest obstacle to testing and refining much of the existing technology. In addition, restricted budgets and manpower limit the field testing, pilot testing, and demonstrations needed for this refinement. Ideally, a technology development plan would exist that prioritizes needs and has sufficient resources to take advantage of any testing, demonstration, etc., opportunities regardless in which Region they occur.

2. Limitations on response due to laws, policies, etc.: Because DFTM outbreaks can develop very rapidly and often at unexpected locations, they can be difficult to detect very far in advance despite our early warning systems. This can sometimes make it difficult, if not impossible, to comply with the NEPA timeframes and still mount a rapid attack on a newly detected outbreak. Perhaps a programmatic DFTM EIS prepared in advance of anticipated outbreaks could overcome this problem.

3. Perceived issues:

a. Stands less than 50 years old are seldom defoliated by the tussock moth. It is suspected that as tree vigor declines in mature and overmature stands, there is an increasing predisposition to defoliation.

b. Forest Plans for those Forests with potential DFTM problems address this pest quite adequately in a general way. Statements from these Plans are:

> "The protection of the timber resource from insect and disease will be emphasized and given priority through silvicultural treatments.
>
> "The Forest will practice and encourage IPM.

"The Forest will use silvicultural methods which will reduce pest problems.

"Consider all methods of controlling insects and diseases."

c. The primary factor triggering action against previous DFTM outbreaks has been the threat to the timber resource. Much of the pressure to respond has come from large timber companies (Boise Cascade and Potlatch Inc.) whose lands are intermingled with public lands. Some past projects have become very political.

d. Good "inform and involve" programs have accompanied past outbreaks. Thus, the local publics are quite well informed of this pest and supportive of management actions.

e. (Discussed earlier)

f. (Discussed earlier)

g. (Discussed earlier)

h. (Discussed earlier)

i. DFTM outbreaks often occur more frequently and impacts are more severe on private land than on National Forest land. The main reason for this is that much of the private land is in the lower elevation transition zone between the pines and Douglas-fir/true firs (the hosts of DFTM). Fire suppression and prior harvesting of the higher valued pines have allowed these nonseral species to expand their range. This is an area of greater moisture stress for the Douglas-fir/true firs, thus making them more susceptible to DFTM predation.

<u>Recommendations</u>

Action needed:

1. Testing and validation of the DFTM outbreak, and socio-economic impact models.
2. A better definition of site and stand conditions that influence susceptibility to the DFTM and how these conditions can be modified silviculturally.

3. Additional development and refinement of direct suppression techniques. Formulations, concentrations, dosages, etc., of Bt have not been thoroughly evaluated against the DFTM. Several potential strategies with the NPV have not been evaluated. These include treating the outbreak in the first or second year of its cycle; treating only "epicenters" aimed at initiating an epizootic throughout the infestation; strategic spraying of key areas (e.g., ridges, canyons, etc.), relying on atmospheric transport of the virus throughout the infestation; etc. There is much remaining to be done with development and technology transfer using the DFTM pheromone as a preventive/ suppressive tool.

FUSIFORM RUST

Steven W. Oak

- Fusiform rust - Cronartium quercuum (Berk.) Miy. ex Shirae f. sp. fusiforme

Ecosystems and Geographic Area.--Southern pine plantations and natural stands in the Piedmont and Coastal Plain of the South Atlantic and Gulf Coast states.

Background.--Fusiform rust is a management concern in loblolly and slash pine seed orchards, nurseries, forest plantations, and natural stands throughout the Southeast. Significant damage occurs in Virginia, North and South Carolina, Georgia, Florida, Alabama, Mississippi, Louisiana, Texas, and Arkansas. While extremely high infection levels can occur throughout the range of fusiform rust, incidence (hazard) maps show that for both preferred hosts, Georgia suffers the most.

Loblolly and slash pines cover a combined area of about 43.5 million acres, with nearly three-fourths in loblolly pine (FIA, unpublished data). Just over half is in private, nonindustrial ownership, while most of the remainder is owned by forest industry (Tables 1 and 2).

The range of fusiform rust nearly overlaps the range of its two major hosts. Only in south central Florida, where no alternate oak host exists, and in the extreme northern part of the loblolly pine range can susceptible pines grow without risk of infection.

Rather than being cyclic in pattern, as with some forest insect pests, fusiform rust is a chronic problem throughout its range. In the presence of inoculum and susceptible hosts, infection biology is governed by micro-climate, specifically temperature and humidity. Suitable conditions occur in some parts of the disease range in every year. Cyclic patterns can be detected locally, as in the case of forest tree nurseries. However, over a period of several years, these differences tend to be minimized within a specific hazard zone.

Damage occurs in young trees from mortality and in older trees from stem breakage and product degrade. Infection occurs either through new foliage or directly on succulent stem or branch tissue. Spindle-shaped swellings eventually result. If branch infections are close enough, the fungus may grow into the stem before the branch is killed. Most direct tree mortality occurs before trees exceed 10 years old. Indirect mortality loss occurs when stems weakened by galls are broken by wind. Affected portions of stems make inferior products and must be culled when solid wood products are the objective.

Acres Affected.--Fusiform rust is the most costly disease in southern forestry, and it has been increasing. The average annual rate of increase (new acres infected) is estimated at 3.1 percent (FIA, unpublished data). Nearly one-

third (32 percent) of the area within the host range is affected at the 10 percent rust incidence level or greater. The most recent data from 1983 showed that 13.9 million acres of slash and loblolly pine stands were in that class (Table 3, Anderson 1985). By applying the annual estimated increase over the intervening years, the current figure is estimated at 15.5 million acres.

Control Responses.--Land managers usually do not act when incidence is only 10 percent. Higher incidence is the trigger for remediation. Though influenced by stand stocking, management action is usually warranted when stem infection exceeds 30 percent. At this level, land managers consider deploying rust resistant planting stock. In 1983, there were 6.1 million acres in this class (Table 4). Of this, about 2.5 million acres had over 50 percent stem infection (Anderson 1985). When stem infection is this high, the stand is a candidate for regeneration (often pre-commercial harvest) and may be converted to other, more resistant or immune, species.

Losses.--While losses are not quantified southwide, they can be projected from data available for five states. Projected dollar losses for replanting and product losses were $31.4 million in 1983 in Florida, Georgia, North Carolina, South Carolina, and Virginia (Table 6, Anderson 1985). Volume killed was 10.8 million cubic feet. The five states represent 63 percent of the southwide acreage in the 50 percent or greater infection class. If loss rates are the same in the remaining states, total losses exceeded $49 million and 17 million cubic feet in 1983.

Other resources are not appreciably affected by severe fusiform rust infection. Wildlife habitat may be improved by the random openings established when rust-infected trees die, but this has not been documented. Fire risk may be greater in heavily infected stands when trees die (adding fuel) or when basal galls occur. Galls tend to be resin-soaked, and if fire occurs, infected trees would be killed.

Historical Perspective.--This disease was not always as serious as it is currently. Prior to 1930, fusiform rust was a native, but relatively innocuous, part of natural slash and loblolly pine forests. Frequent, uncontrolled wildfires kept the alternate host, oak, at relatively low levels. During the 1930's, artificial regeneration of these pines by planting became commonplace as abandoned agricultural land was reforested. This trend was accelerated by activities of the newly formed Soil Conservation Service and the Civilian Conservation Corps, and in the 1950's by the Soil Bank Act. Industry also became an integral part of the southern forestry scene and tree planting was a cornerstone of management. Loblolly and slash pines were pushed to the limits of their natural range and beyond in large, even-aged stands less diverse than the natural stands which had previously dominated. Over 20 million acres have been planted since the 1930's. Fire control programs were effective in their task, but this success permitted the proliferation of the oak alternate host previously suppressed by frequent wildfires. The result of these historical trends is the current epiphytotic. If current estimated annual increases are accurate and effective controls are not forthcoming, the estimated affected acres will increase from 15.5 million in mid-1987 to 16.2 million by the end of 1988, to 17.2 million by the end of 1990, and to 23.3 million by the turn of the century.

There is no doubt about the parallel histories of southern forestry and fusiform rust. The same factors that have made the South the nation's woodbasket have been responsible for the pre-eminence of fusiform rust among southern

forest diseases. Activities which may have limited disease distribution and impact within the historical framework of the artificial regeneration explosioninclude: 1) effective nursery pest management, 2) limiting the extension of the range of susceptible genotypes and greater emphasis on rust resistance in first generation tree breeding programs, 3) sanitation/salvage thinning, and 4) maintaining a diversity of forest types and age classes in a mosaic land- scape.

Symptoms on infected, nursery-grown seedlings ready for outplanting are often inconspicuous and sometimes absent entirely. Some stands were regenerated with infected seedlings that eventually died. Perhaps of greater long-term consequence than plantation failure was the importation of rust strains not native to the area, because many nurseries are far removed from regeneration sites.

During the 1950's and 1960's, slash pine was widely planted on marginal sites outside of its natural range. This was because it exhibited better growth and survival than the native loblolly in some tests. Unfortunately, it also has greater susceptibility to fusiform rust. This resulted in proliferation of inoculum and may have contributed to continuing disease intensification. Similarly, loblolly pine seed sources with attractive growth and yield characteristics were moved to other areas to capitalize on this superiority over native sources. They were then exposed to rust inoculum that was genetically different than the fungus at the tree's site of origin, effectively forfeiting resistance acquired through natural selection.

Stands established under initiatives of the Soil Conservation Service, Civilian Conservation Corps, and the Soil Bank Act predate active tree breeding programs. In the late 1950's, these programs gained momentum, but emphasis was placed on traits other than rust resistance. Greater emphasis would have resulted in more resistant planting stock available for earliér deployment.

Removing diseased trees in sanitation/salvage thinnings could have been useful in limiting disease impact, but this option is limited. It would have been applicable only where sawtimber was the management objective and only where incidence was not so high as to leave a poorly stocked stand. Some diseased trees would have remained in the stand to maintain adequate spacing and stocking. It is doubtful that thinning would have been used much strictly as a rust management strategy. Inoculum would have been reduced somewhat by eliminating some disease trees, but perhaps not below a threshold that would translate into reduced incidence or distribution in other stands.

Large, continuous acreages of even-aged stands of non-native seed sources also contributed to inoculum buildup. Damaging rust infections occur early in the life of the stand (within 5 years), and by keeping stand size small and interspersing stands of different ages, the impact over large areas in any one year would be reduced and inoculum kept within limits.

Because of the intensity of southern forestry, it is doubtful that fusiform rust would have remained the botanical curiosity it was prior to the 1930's. However, if employed during the expansion of southern forestry, these strategies would certainly have reduced the rust problem from what we see today. It is impossible to quantify these effects.

Management Options.--The only true disease control occurs in forest tree nurseries through the use of fungicides. Virtually every nursery in the South where fusiform rust is even a slight risk (about 90 percent of all nurseries)

uses the fungicide triadimefon (Bayleton) to protect the slash and loblolly pine crops. In high-risk areas, even longleaf pine is protected. The fungicide is extremely effective; requires one-tenth as many applications as earlier, less effective fungicides; and has curative as well as residual effect. Southwide, over 95 percent of the estimated 2 billion seedlings produced each year are protected by fungicides against fusiform rust (C.E. Cordell, personal communication).

In forest stands, disease impact is managed in two primary ways--through silvicultural methods and through the exploitation of inherent genetic resistance. The only silvicultural options that are practical and widely applied are increasing planting density to compensate for rust-caused mortality and regenerating heavily infected stands. Thinning may reduce overall rust impact, but it is seldom used strictly as a rust management strategy. It achieves a measure of stand improvement while accomplishing overriding product objectives.

There is no estimate of the number of acres where stocking is increased, but it is extremely common where rust is a perceived threat. The cost of increased stocking would be almost entirely in the cost of seedlings. Increasing stocking 25 to 30 percent would cost between $4.00 and $7.00 per acre. Far from indirectly benefiting other untreated acres, this treatment might actually serve to increase rust incidence. More trees planted per acre may translate to more infected trees per acre, which increases inoculum and perhaps increases infection elsewhere. Further, if rust does not claim the expected percentage of stand stocking, then an overstocked stand results.

Stand liquidation and regeneration is an option practiced when rust infection will likely result in excessive mortality and low stocking early in the life of the stand or where it precludes sawtimber production in long rotations. It is estimated that 5 percent of the acres with 50 percent rust incidence are so treated (R.L. Anderson, personal communication). This amounts to approximately 125,000 acres per year. The costs of this treatment are variable, depending on the particular stand condition. Direct cost for site preparation, seedlings, and planting is about $150 per acre, or an estimated $18.75 million southwide. This would be raised by adding opportunity costs, but lowered by commercial products that could be removed from salvaged stands. Indirect benefits to other untreated acres cannot be quantified at this time. Presumably, inoculum would be reduced by removing heavily infected stands.

Other silvicultural methods for managing rust that are not widely used include: 1) reducing oak populations (because of wildlife food and habitat benefits, and aesthetics), 2) pruning or excising rust galls (because of labor costs), and 3) seed tree/shelterwood regeneration systems utilizing disease-free trees (because of longer regeneration time and less control over stocking in the new stand).

The use of genetically resistant trees affords the best opportunity for reducing the impact of fusiform rust southwide. This is accomplished by using less susceptible southern pine species such as shortleaf and longleaf pines on suitable sites; using loblolly instead of slash pine where appropriate; using inherently resistant sources of loblolly pine; and by improvement in rust resistance through tree breeding programs. There are no estimates of acres converted to suitable and more resistant tree species because of fusiform rust. Species conversion is often employed when other factors besides rust (such as weather damage or poor yields) intervene. However, improvement in

rust resistance through tree breeding and deployment of resistance sources have been estimated.

Tree breeding is now entering its second generation in the South. First generation selection did not put a high priority on fusiform rust resistance, and as a result, a large improvement was not realized. More recent concentration of effort on rust resistance has resulted in remarkable gains. Reductions in rust incidence of 40 to 50 percent are commonly reported for both loblolly and slash pine (Powers and Krause 1982, Griggs and Schmidt 1977). This improvement is in addition to gains realized in yield, wood quality, stem straightness, and other characteristics. Unfortunately, rust-improved material has been deployed only recently and on a small fraction of the acres available for treatment. The cost of orchard-improved seedlings is about $10 per 1,000 more than unimproved stock (Redmond and Anderson 1986). It would cost $5 to $7.50 per acre more to regenerate with rust-improved stock than with unimproved stock.

The planting of inherently more resistant sources has been the most widely used genetic solution to date. Slash pine shows very little source-related resistance, but loblolly pine from Texas, Maryland, and Livingston Parish, Louisiana is known to display more resistance than many sources native to regeneration sites. Estimates are similar to those for orchard-improved stock (50 percent rust reduction [Wells 1985]), but these sources do not possess other desirable characteristics present in orchard-improved stock. Nevertheless, their use means the difference between a well-stocked stand and no stand at all in many high rust hazard areas. Resistant sources are deployed on about 20 percent of the acreage planted by reporting industries annually (Wells 1985). Williston (1980) reports that about 1.3 million acres are planted each year, of which about 80 percent (about 1 million acres) is loblolly pine. The rate of Livingston Parish deployment (20 percent) applied to annual acres planted to loblolly pine results in an estimated 200,000 acres per year regenerated with resistant stock. Over the last 15 years, about 3 million acres were so treated, which amounts to about 7 percent of the current host type.

The 50 percent reduction in rust incidence presumed on acres planted with resistant loblolly pine has been inexpensively purchased. Livingston Parish loblolly pine sells for only $6 per 1,000 seedlings more than woods-run seedlings. This translates to less than $1 per planted acre.

Deployment of equally resistant seed orchard-improved stock that possesses other desirable traits will explode in the next few years as orchards incorporating fusiform rust resistance come into full production. Rust reduction will then be coupled with yield and quality increases that will result in substantial net product increases. A Florida forest industry indicated a 7 percent yield increase measured at the mill from a harvest of a stand established with rust- and growth-improved trees.

Technology.--Current technologies for preventing or reducing fusiform rust are generally adequate conceptually, but practical improvements are needed, especially in the area of hazard prediction. A site-specific method for assessing the risk of rust infection would guide deployment of resistant stock that is very valuable and currently in short supply. A system that predicts rust hazard before regenerating a stand or even in the absence of susceptible pines would be most helpful.

Further advances in genetic solutions to the rust epidemic are likely. These include strategies based on vegetative propagation, tissue culture, basic DNA

research, and other biotechnologies, in addition to more immediately practical efforts aimed at early resistance screening. An index that more accurately predicts field resistance from greenhouse symptoms is already in use at the USDA Forest Service Resistance Screening Center, Asheville, N.C., for slash pine, and a similar loblolly pine index is being developed.

Policy.--While existing law and governmental policies do not present obstacles to the use of existing rust management technologies, neither do they encourage their use. Incentive programs (e.g., cost sharing, cooperative agreements) could advance the deployment of existing genetically resistant planting stock and encourage the expansion of the production capacity of federal, state, and industrial forestry concerns. Future regulation of biotechnology research and application could limit potential gains from those activities, but such law and policy is not yet in place.

National Forest Planning.--The National Forests planning processes do not yet consider the influence that fusiform rust has on projected yields and product flows. Rust is recognized as one of many pests that influence management of the National Forests, but losses are not quantified and management options are not spelled out. Reference is made to pertinent literature that details disease biology and regional losses, but which provides only general management options that are not tailored to the range of public land management objectives. Public perceptions are not likely to influence forest management decision making with regard to fusiform rust, except perhaps to hamper deployment of genetically resistant planting stock. This is because of a general suspicion of plant breeding, borne out of commonly known disease epidemics in corn and wheat. These disasters resulted from breeding to a very narrow genetic base, leaving little capacity in the plant to adapt to new strains of pathogens. Similar occurrences in forestry are very unlikely because of far-reaching differences in host genetic diversity, pest life cycles, production systems, environmental diversity, and breeding goals. Nevertheless, objections may remain. Even greater resistance may be expressed when the results of biotechnology research in forestry are ready for field use.

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Table 1.--Area of timberland in the South with loblolly pine forest type, by state and ownership.

State	Total All Owners	Ownership National Forest	Other Public	Forest Industry	Other Private
		(Thousand acres)			
FL	539	5	29	239	266
GA	5,130	68	221	1,583	3,258
NC	3,409	43	127	1,148	2,091
SC	3,870	279	165	1,326	2,100
VA	1,773	---	64	796	913
AL	4,413	122	42	1,329	2,920
AR	2,234	313	16	1,103	802
LA	3,580	114	73	1,608	1,785
MS	2,917	296	71	705	1,845
OK	76	4	2	45	25
TN	276	23	9	57	187
TX	3,229	259	28	1,385	1,557
TOTAL	31,446	1,526	847	11,324	17,749

Table 2.--Area of timberland in the South with slash pine forest type, by state and ownership.

State	Total All Owners	Ownership National Forest	Other Public	Forest Industry	Other Private
	(Thousand acres)				
FL	5,216	299	289	2,664	1,964
GA	4,058	4	138	1,794	2,122
NC	195	--	9	149	37
SC	373	--	58	132	183
VA	--	--	--	--	--
AL	716	46	17	267	386
AR	--	--	--	--	--
LA	609	70	12	301	226
MS	671	131	57	196	287
OK	--	--	--	--	--
TN	--	--	--	--	--
TX	212	9	--	167	36
TOTAL	12,050	559	580	5,670	5,241

Table 3.--Slash and loblolly pine stands in the South that have about 10 percent or more of the trees infected with fusiform rust on or within 12 inches of the main stem--1983.

State	Landownership Class				
	National Forest	Other Federal	State	Private	Total by State
			Acres		
AL	61,900	20,100	20,100	1,938,900	2,041,000
AR	6,500	1,200	800	50,400	58,900
FL	47,000	28,400	22,500	1,020,200	1,118,100
GA	78,500	71,600	14,800	3,871,700	4,036,600
LA	61,300	15,700	31,400	1,461,700	1,570,100
MS	86,500	6,700	6,800	1,585,200	1,685,200
NC	28,700	9,600	9,700	1,296,300	1,344,300
SC	73,081	45,819	14,699	1,362,877	1,496,476
TX	36,500	1,300	1,400	461,800	501,000
VA	0	0	0	6,000	6,000
TOTAL	479,981	200,419	122,199	13,055,077	13,857,676

Table 4.--Slash and loblolly pine stands that have 30 percent or more of the trees infected with fusiform rust on or within 12 inches of the main stem--1983.

State	Landownership Class				
	National Forest	Other Federal	State	Private	Total by State
			Acres		
AL	26,631	8,138	8,138	773,156	816,063
AR	2,282	427	213	17,951	20,873
FL	31,552	19,063	15,129	640,446	706,190
GA	32,309	36,564	5,625	2,039,947	2,114,445
LA	20,954	5,456	10,913	507,470	544,793
MS	38,991	2,758	2,852	648,262	692,863
NC	8,074	2,782	2,860	370,650	384,366
SC	33,258	14,114	20,829	569,709	637,910
TX	10,850	438	65	204,462	215,815
VA	0	0	0	4,300	4,300
TOTAL	204,901	89,740	66,624	5,776,353	6,137,618

Table 5.--Slash and loblolly pine stands that have about 50 percent or more of the trees infected with fusiform rust on or within 12 inches of the main stem--1983.

State	Landownership Class: National Forest	Other Federal	State	Private	Total by State
	Acres				
AL	11,180	3,366	3,366	319,800	337,712
AR	1,018	156	78	6,578	7,830
FL	12,077	7,296	5,791	244,631	269,795
GA	12,776	7,834	2,419	877,196	900,225
LA	8,022	2,112	4,225	196,450	210,809
MS	16,370	1,133	1,175	266,373	285,051
NC	2,959	1,030	1,069	138,946	144,004
SC	13,479	5,901	8,710	237,941	266,031
TX	3,965	161	24	74,973	79,123
VA	0	0	0	2,416	2,416
TOTAL	81,846	28,989	26,857	2,365,304	2,502,996

Table 6.--Mortality and dollar losses attributed to fusiform rust in five states using the computerized loss assessment system--1983.[1]

Host/Impact	Unit	State				
		Florida	Georgia	North Carolina	South Carolina	Virginia
Loblolly pine:						
Mortality	Dead trees	926,900	8,658,400	1,225,000	1,482,600	308,200
	Cubic feet	274,400	3,694,300	843,100	1,517,200	243,300
Cost of replanting	Dollars	268,400	1,465,960	103,598	676,600	0
Cordwood loss	Dollars	1,680,233	9,749,390	3,107,896	3,464,000	0
Sawtimber loss	Dollars	320,534	5,039,864	113,766	1,740,627	40,290
TOTAL		2,269,167	16,255,214	3,325,260	5,881,227	40,290
Slash pine:						
Mortality	Dead trees	5,636,900	3,724,100	0	2,114,100	0
	Cubic feet	1,842,200	1,529,200	0	853,100	0
Cost of replanting	Dollars	74,200	66,045	0	0	0
Cordwood loss	Dollars	26,841	1,986,108	0	247,536	0
Sawtimber loss	Dollars	458,283	692,816	0	41,454	0
TOTAL		559,324	2,744,969	0	288,990	0

OTHER PESTS AND FOREST DECLINE IN THE NORTH

Includes the following individual papers and authors:

Ash decline	M.Mielke
Beech bark disease	M.Mielke
Birch decline	B. Ford
Hypoxylon canker	L. Merrill
Jack pine budworm	S. Munson
Maple decline	I. Millers
Oak decline	B. Acciavatte
Native oak leaftiers	B. Acciavatti
Sapstreak disease and decay	M. Mielke
Saratoga spittlebug	P. Rush
Tent caterpillar	B. Ford
Red spruce and balsam fir decline	M. Miller-Weeks
White pine weevil	J. O'Brien
White trunk rot	L. Merrill
White pine blister rust	J. O'Brien

ASH DECLINE

II. Ecosystems and geographic "area covered" in this analysis:
Elm-ash-cottonwood and maple-beech-birch types in the northern forest.

III. Very brief history and biology of pest or group of pests:

1. Distribution
   a. Description of host vegetation (preferred and secondary):

Primary species affected is *Fraxinus americana* (white ash), also affected is *F. pennsylvanica* (green ash).

b. What percent of the Northeastern area is occupied by this host type:

33% of commercial forest area has a white ash component. White ash comprises about 4.5% of the total hardwood cubic foot volume.

2. Life cycle:

This is a disease complex associated with many factors including a MLO (mycoplasma-like organism), canker-causing parasites, freeze damage to the cambium and drought stress. The MLO is thought to be insect transmitted.

3. Cycles and triggers:

The precise etiology of ash decline is not known. Multiple agents are thought to be involved. Recently a MLO has been associated with many declining ash. Symptoms include the sudden onset of slow radial growth followed by reduced apical growth, stem and branch cankers, epicormic sprouts, witches brooms, sparse and chlorotic foliage which are often tufted at ends of branches and the nodes,and gradual branch dieback leading to tree death within 2-10 years. Moisture stress has long been suspected as a major factor in the syndrome with the MLO providing an additive influence since both cause stomatal closure and retard growth.

4. How have man-caused changes in natural dynamics of the forest ecosystem influencing fire activity, ecosystem diversity, and nutrient cycling affected the incidence of pest outbreaks?

There are no apparent man-caused changes to the environment that initiated or accelerated the spread of ash decline. Climate is suspected as a major influencing factor. Indirect effects are possible in-so-far as man has influenced changes in the climate.

IV. Summarize the current status of this pest or group of pests.

1. Status of infestations or infection:
Ash decline continues unabated throughout most of the range of ash. New York appears to be the most heavily affected state. Mortality is also reported in Ohio, Iowa and Indiana.

2. Percent of host type currently infested: 75%.

3. Acres infested: Best estimate is 40 million acres.

4. Probable course of the infestation or infection

a. When could an infestation or infection start?
No single causal agent has been definitively linked to the initiation of ash decline. Moisture stress in all its manifestations, including MLO, freeze damage to the cambium and drought stress appear to alter the host enough to precipitate decline.

b. Where might it start?

Where ever it does not now exist.

c. What are the expectations about future distribution and extent?

It appears to be a widespread, endemic problem in forests, woodlots, roadside trees and hedgerows. The presence of abundant healthy regeneration and saplings offer hope that ash as a resource is not threatened.

d. Where will it be (area and cycle) in 1988, 1990, ten years?

It will probably expand into presently unaffected areas and continue its historic linear rate of spread in areas where it presently occurs. About 71% ash trees in NY are estimated to be dead or declining. Decline has continued on plots monitored in Ohio, Indiana, and Iowa.

5. What may have caused or triggered this infestation or infection?
a. Discuss both primary and secondary factors. (Specify not only the immediate biological causes but also the chain of events leading up to those causes. Consider management decisions and cultural, economic, climatic and other events.)

The relationship between incidence, severity, and rate of ash decline development and spring drought is uncertain and somewhat contradictory. However, white ash is particularly vulnerable to drought induced stress because it is ring porous and has an unusually low moisture content. MLO infections cause reactions similar to water stress e.g. stomatal closure and growth retardation. Decline may be initiated by drought and/or MLO"s and aggravated by facultative parasites. Trees, once infected, do not usually recover.

b. To what extent is aging of the nation's forests related to the incidence of this pest outbreak?

Older trees appear to be most severely affected by the decline syndrome. The random onset of decline in young ash trees suggests the involvement of an infectious agent such as a MLO. However, observations suggest seedlings and saplings are replacing the dead and declining ash overstory. It is not known whether the decline syndrome is a direct effect of age. Certainly the cumulative effects of a lifetime of various stresses shifts the energy balance in favor of the multiple causal agents.

6. Describe the possible responses
a. Acres treated by type of treatment:

No known direct controls are available for MLO's. Rouging of MLO infected nursery stock would seem to be important in preventing their spread to urban, ornamental and forest plantings. To date this is not yet routine. Since the disease increase is linear over time, if an infectious agent is primarily involved it must spread from another source or spread very slowly from tree to tree. Salvage, therefore, is not a critical factor in slowing the spread of the disease.

b. Percent of total infested acres treated: 0

V. <u>Describe the expected accumulative impacts associated with this pest or complex of pests.</u>

1. General impacts:

Short term loss of a commercially valuable timber species. Pending resolution of the precise etiology of ash decline, the long term viability of ash as a resource is unknown.

2. Specific impacts -- expected changes in yield per acre (vegetation, primarily timber, recreation, wildlife) over the next decade due to damage by this complex of pests).

Little loss in site productivity should be expected as associated species and young ash are replacing the dying overstory. The current stumpage for ash is about $100/MBF, and traditionally, strong demand for ash has kept its value high. The value of quality ash will probably increase as availability decreases. Producers of specialty products such as sporting equipment and handlestock should be concerned about the short-term availability of quality ash.

Some municipalities have planted ash extensively. If the problem is primarily an infectious disease, they could be creating a situation similar to that of American elm and Dutch elm disease.

VI. Control Response(s)

1. What actions could be taken to control this infestation or infection?

Rouging of MLO-infected nursery stock to prevent further spread.

2. What triggers a decision to take action against a forest pest?

Not applicable.

3. What would happen if no action is taken?

Unwitting homeowners, urban planners and forest managers might be planting diseased stock.

4. What could be done to prevent future infestations or infections?

See 1 above, and little else.

VII. Technology Information

1. Describe the adequacy of available technology for prevention or reduction of infestations or infections.

Information on the etiology of ash decline is lacking. Except for planting MLO-free stock, no management guidlines are available.

2. Describe technology needed to prevent, reduce, or control future occurrences of these infestations or infections.

What's needed is basic information on disease etiology and epidemiology. Since the precise etiology of ash decline is not fully known, no sound management alternatives are available, and none are available to deal with the agents known to be involved in the multi-agent complex.
If in fact the MLO or some other unfamiliar organism is primarily responsible then new and cost effective means of detection, evaluation and possible controls will need to be developed.
T

VIII. Treatment Options

1. Describe treatment techniques, accomplishments and costs.

Not applicable.

2. Technique (describe): NA

3. Cost of treatment: NA

IX. <u>Discuss the observed and expected trends of the next decade for this pest or complex of pests.</u>

Wdespread ash mortality has occurred periodically since the early 1930's. Whether the current syndrome is identical is unknown. Observations from 1960 to the present indicate an annual rate of mortality of between 3.3-6.3%. At any given time, 71% of ash are dead or declining. This does not indicate a static condition since many trees that died have been replaced by healthy saplings. This trend will probably continue in the next decade.

X. <u>In addition to the information required elsewhere in this outline, discuss the following:</u>

1. The obstacles, if any, to the use of existing technology for preventing outbreaks of the pest.

No satisfactory technology exists.

2. The limitations placed on effective response to the pest by laws, policies of the Forest Service, and policies of other government (federal, state, local) agencies.

None.

XI. <u>Recommendations</u>

a. Further analysis needed.

We need to analyze the ultimate impact on ash as a long term resource. Is the current reproduction enough to sustain ash as a viable species?

b. Added information needed.

The etiology of decline is not fully understood. We need to know if there are primary predisposing factors we can control. If primary infectious agents are involved we need to develop means to control them. Nurseries need information on how to survey for yellows and take appropriate actions to prevent the spread of the MLO.

c. Actions need now.

Rouging of MLO nursery stock and surveys of areas near sites known to have the MLO.

d. Actions needed within the next 5 years.

Continued survey for the MLO and the development of simple diagnostic tests for MLO's and similar organisms.

BEECH BARK DISEASE

II. Ecosystems and geographic "area covered" in this analysis:

Maple-beech-birch forest type in northern forests

III. Very brief history and biology of pest or group of pests:

1. Distribution
    a. Description of host vegetation (preferred and secondary):

Fagus grandifolia is the sole native host.

b. What percent of the Northeastern area is occupied by this host type

About 21.6% of the northern forest is maple-beech-birch. About 4.0% of the total hardwood cubic foot volume is american beech.

2. Life cycle:

Beech scales (*Cryptococcus fagisuga*) were introduced from Europe in the late 19th century. They are disseminated primarily by wind. Individual scales are intercepted by large overmature beech trees which serve as infestation foci for surrounding trees. Scales have little direct effect on trees, but they enable native *Nectria* spp. to infect trees. Trees are girdled and killed once scale populations build to the point where individual Nectria infections are able to coalesce.

3. Cycles and triggers:

Marked declines in scale populations occasionally occur over large areas. Air temperatures of -37 C are lethal to those insects not protected by snow. Nectria fungi are attacked by mycoparasites but the effects of parasites and predators on Nectria and the scale have not been critically evaluated.

The overall pattern of beech bark disease (BBD) has been described as going through three distinct stages. The so-called "advancing front" is characterized by building scale populations and initial Nectria infections. Mortality begins to occur 3-6 years following introduction of the scale. What follows is the "killing front" during which up to 85% of beech are killed. The "aftermath forest" is characterized by older residual trees, a few resistant trees, and many slow growing defective trees of low value and volume.

4. How have man-caused changes in natural dynamics of the forest ecosystem influencing fire activity, ecosystem diversity, and nutrient cycling affected the incidence of pest outbreaks?

Past harvesting practices have favored the tolerant beech with its capacity to reproduce vegetatively: 1. highgrading of companion species leaving beech

residuals, 2. selective cutting systems without understory treatment and, 3. the occurrence of BBD usually accompanied by salvage without understory treatment. As a result, stands have been created with even higher proportions of beech. The impact of BBD is greatest in such forests. In addition, the disregard for preserving potential and actual resistant trees has resulted in stands of equal or greater susceptibility to BBD.

IV. Summarize the current status of this pest or group of pests.

1. Status of infestations or infection:

Due to the irregular dispersal of scales by wind, all stages of disease development can occur within a limited geographic area. Currently large areas of New England and NY have aftermath forests. The advancing and killing fronts exist throughout New England, NY, Northern PA and isolated remote infestations in WV, VA, and N.E. OH.

2. Percent of host type currently infested:

Approximately 50% of the northern forest with beech has the scale or BBD.

3. Acres infested:

About 15 million.

4. Probable course of the infestation or infection:

a. When could an infestation or infection start?

See section III. 2 above, anytime the scale is introduced into new areas.

b. Where might it start?

Anywhere throughout the range of American beech. The occurrence of BBD 400 km from the general "advancing front" indicates long distance spread is possible.

c. What are the expectations about future distribution and extent?

Beech throughout its range is at risk.

d. Where will it be (area and cycle) in 1988, 1990, ten years?

The scale spreads an average of 10 km/yr by air based on the time it has taken to spread over the area it now occupies. However, long distance spread is possible.

5. What may have caused or triggered this infestation or infection?

a. Discuss both primary and secondary factors. (Specify not only the immediate biological causes but also the chain of events leading up to those causes. Consider management decisions and cultural, economic, climatic and other events).

The introduction of the exotic scale and the continuity of host type is responsible for the maintenance and continued spread of BBD. Management has affected incidence, spread and impact are discussed in section III. 4.

b. To what extent is aging of the nation's forests related to the incidence of this pest outbreak?

Aging of forests is only related to the incidence of BBD in so far as large overstory beech provide a greater target area to intercept wind deseminated scales from infested to non-infested areas.

6. Describe the possible responses

a. Acres treated by type of treatment:

No direct controls are practical. Silvicultural manipulation to minimize impact of BBD prior to its introduction and encouraging beech resistant to scale are the preferred means to manage BBD.

b. Percent of total infested acres treated:

Less than 1% is treated specifically for BBD. An unknown acreage is salvaged and a few thousand acres/yr are treated to control competition from beech sprout thickets which has the effect of minimizing future impact by BBD.

V. Describe the expected accumulative impacts associated with this pest or complex of pests.

1. General impacts:

Observations suggest 85% of overstory trees are killed during passage of the killing front. Potential $ loss according to a 1982 study in WV was $250/acre using values of $40/MBF. In addition, there is reduced productivity in the aftermath forest.

2. Specific impacts -- expected changes in yield per acre (vegetation, primarily timber, recreation, wildlife) over the next decade due to damage by this complex of pests):

Immediate impacts are rapid, widespread mortality in the killing front and alteration of management plans if salvage operations are initiated. Loss of mast producing trees is very important in those areas where beech is the sole mast producer. Aftermath forests consist of many defective beech of low value and volume. Precise figures on yield/acre lost are unavailable. The area that will become infested over the next decade should continue to expand at the observed rate of 10 km by air/yr. Additionally, BBD has been found in Ontario, Canada threatening the beech resource in Michigan from both the north and the south.

VI. Control Response(s)

1. What actions could be taken to control this infestation or infection?

Direct control is impractical. Anticipate the arrival of BBD and take steps to reduce the amounts of beech while preserving potential and actual resistant indivduals.

2. What triggers a decision to take action against a forest pest?

Any treatment to achieve #1 above are usually incidental to BBD management. Treating understory beech thickets to promote intolerant companion species has positive effects vis a vis BBD. Salvage is conducted to minimize $ loss but has a negative effect if sprout thickets are not simultaneously controlled.

3. What would happen if no action is taken?

The $ loss following passage of the killing front will be whatever beech will command at that time. The value of beech should increase commenserate with decreasing availability of high quality beech. The long term productivity in the aftermath forest is lower. Long term effects on wildlife are minimal, but the immediate loss is great in those areas where beech is the sole mast producing species.

4. What could be done to prevent future infestations or infections?

See VI. 1. Monitor, anticipate the arrival of BBD and reduce the amount of beech and favor resistant individuals.

VII. <u>Technology Information</u>

1. Describe the adequacy of available technology for prevention or reduction of infestations or infections.

Adequate technology to predict actual resistance of trees prior to the passage of the killing front is not currently available. Infestations can be postponed if large "wolf trees" that protrude through tops of forest canopies are eliminated. The willingness to undertake the proper steps to reduce the amount of beech in stands which can be expected to get the disease within the length of the current rotation will minimize the impact of BBD.

2. Describe technology needed to prevent, reduce, or control future occurrences of these infestations or infections.

We need a means to accurately predict individual tree resistance to the beech scale using phenotypic characteristics or some other ready diagnoses in the "scale free" areas, "advancing" and "killing" fronts.

VIII. <u>Treatment Options</u>

1. Describe treatment techniques, accomplishments and costs:

a. Monitor status of disease agents, b. reduce proportion of beech in stands, c. select against large "wolf trees" with rough bark, d. treat susceptible sprout thickets, e. salvage, f. preserve resistant trees and their sprouts to enhance the resistant character of stands in the long run.

2. Technique (describe):

Herbicide treatment of beech thickets using Glyphosate is effective and environmentally safe.

3. Cost of treatment:

Glyphosate treatments cost between $30-$50/acre.

IX. Discuss the observed and expected trends of the next decade for this pest or complex of pests.

See sections IV 4 d, and III 3.

X. In addition to the information required elsewhere in this outline, discuss the following:

1. The obstacles, if any, to the use of existing technology for preventing outbreaks of the pest.

1. Resistance to the use of herbicides in the control of sprout thickets. The Allegheny NF is perhaps the only public organization willing to undertake this measure and only because of the high value of the black cherry it promotes.
2. The reluctance of managers to address beech management because of its current low market value and its perceived "weed tree" status.

2. The limitations placed on effective response to the pest by laws, policies of the Forest Service, and policies of other government (federal, state, local) agencies.

XI. Recommendations

a. Further analysis needed.

Identify stands of beech that are at risk for BBD within the next decade (based on proximity to known infestations and the observed rate of spread). Make those stands high priority for implementation of recommended actions. Ensure that aftermath forests are properly managed to increase productivity and enhance the inherant resistance character of the beech resource. Resistance is clearly identifiable in aftermath forests.

b. Added information needed.

How to identify phenotypic characters of resistance in scale free zones and in the advancing and killing fronts.

c. Actions needed now.

Implementation of proven strategies to minimize the impact of furture infestations and improve the quality of aftermath forests.

d. Actions needed within 5 years.

Increase the area in which "a" and "c" are implemented. The areas of major concern in the next 5 years are those in the scale free areas adjacent to the advancing and killing fronts. Salvage operations will need to be conducted in stands now in the killing front. Beech resistance to scale can be discerned during the advancing front and should be retained in pre-emptive salvage efforts.

BIRCH DECLINE

I. Other Forest Pest or Forest Decline:

Birch decline caused by, bronze birch borer (BBB) - *Agrilus anxius*, birch leaf miner (BLM) - *Fenusa pusilla*, and several other species of birch leaf mining sawflies and lepidopterans

II. Ecosystems and geographic "area covered" in this analysis:

All species of birch throughout northern forests are hosts. Ecosystems are birch, birch-aspen, aspen-birch conifer, northern hardwoods, and urban forests.

III. Very brief history and biology of pest or group of pests:

1. Distribution
   a. Description of host vegetation (preferred and secondary)

Paper birch is the most preferred host with imported birch a close second due to its placement in the highly susceptible urban forest. Gray birch and yellow birch follow in order of preference. Sweet and river birch are secondary hosts.

   b. What percent of the Northeastern area is occupied by this host type

The hosts are found throughout NA and are represented on nearly 75,000,000 acres, including urban forests. The majority of birch grow in the northern portions of the Lake States, NY, NH, VT and ME.

2. Life cycle

Bronze birch borer (BBB) begins as an egg in bark crevices of the host tree. The hatched larva bores into the cambiam where it feeds on the woody tissue along meandering tunnels. At maturity in 1 to 2 years, the larva constructs a pupation chamber and pupates. Adult beetles emerge in the spring to feed on leaves, mate, and lay eggs.

Birch leaf miner (BLM) has 2 to 4 generations a year beginning with adults emerging from the soil in early May. The parthenogenetic females lay eggs in slits cut into the leaf surface. The larvae feed on leaf tissue between upper and lower surfaces. When fully grown, larvae drop to the soil, pupate and emerge to lay eggs of the next generation. These eggs of later generations are laid at twig terminals so that hatching larvae may attack new leaves. Birch produces new leaves all summer and each new leaf may be attacked by BLM. This insect overwinters as a pupa in the soil.

3. Cycles and triggers

There seems to be a constant high population of BLM with no cycle evident. BBB depends upon available food and weather to maintain populations. No cycle is evident.

4. How have man-caused changes in natural dynamics of the forest ecosystem influencing fire activity, ecosystem diversity, and nutrient cycling affected the incidence of pest outbreaks?

Planting of birch in the urban and suburban forest, especially cutleaf European varieties in yards, parks and golf courses, contributes greatly to maintenance of high populations of BBB and BLM. Seed tree harvests that leave exposed yellow birch as a seed source result in attacks by BBB. Similar harvests that leave paper birch exposed on the edges of stands increase their vulnerability to BBB. Highway construction, farm field enlargement woodland home building, and fire contribute to increases in BBB damage.

IV. <u>Summarize the current status of this pest or group of pests</u>.

1. Status of infestations or infection

The infestations of BBB and BLM remain at constant levels throughout NA. Increases in BBB are localized according to cultural activity.

2. What percent of the host type is currently infested.

100 percent of host types are infested to varying degrees.

3. Acres infested

75,000,000 acres. Outbreaks of BBB are present on some 1,000,000 acres and BLM is on some 60,000,000 acres.

4. Probable course of the infestation or infection
   a. When and, b. Where might an infestation or infection start?
   c. What are the expectations about future distribution and extent?
   d. Where will it be (area and cycle) in 1988, 1990, ten years?

The BLM is an imported insect as are most of the other leaf miners. The infestations have spread to wherever birch grows. BBB outbreaks begin when cultural practices favor it (III 4) or when a prolonged drought occurs. This situation will continue in the future and remain consistent through the next decade.

5. What may have caused or triggered this infestation or infection?
   a. Discuss both primary and secondary factors. (Specify not only the immediate biological causes but also the chain of events leading up to those causes. Consider management decisions and cultural, economic, climatic and other events.)

Cultural practices contribute greatly to outbreaks of BBB. The beetle is native and infestations have been in NA since birch reclaimed land covered by the last ice age. BLM was introduced from Europe and spread at will. Little is known about leafminers and why they remain at high levels over time. BBB,

however, gets started when birch is exposed to sunlight, drought, heat, mechanical damage, and defoliation. The beetle attacks healthy trees but larvae fail to survive. They are able to survive in stressed trees. The trees are further stressed by BBB feeding which contributes to increased survival of offspring for several generations.

People favor birch for aesthetic reasons. They plant paper birch and European birch in their yards and other exposed places where the trees are under weather and climatic stress. People build homes in the "country" and cut down many trees except paper birch. The movement of people to the suburbs has contributed to BBB outbreaks and has maintained BLM food supplies.

Long warm spells stress paper, yellow, and gray birch which makes them more vulnerable to BBB. The introduction from Europe of BLM and other leaf miners contribute to stress that favors BBB.

b. To what extent is aging of the nation's forests related to the incidence of this pest outbreak?

Old birch are more vulnerable to BBB than are young birch. Birch left in primitive or wilderness areas eventually will be killed by BBB and not replaced since birch is an early successional species that requires a site distubance to regenerate.

"Residential" birch in suburbia live about 25 years on average then are killed by BBB.

6. Describe the possible responses
   a. Acres treated by type of treatment
   b. Percent of total infested acres treated

The acres treated are unknown. Some prevention is practiced in harvesting, but none in road building. Individual homeowners may treat to reduce BLM. Many individual trees in suburbia are treated each year for BLM control, but it's an insignificant percentage of the total type.

V. Describe the expected accumulative impacts associated with this pest or complex of pests.

1. General impacts

General impacts have been of little concern to foresters. Home owners will continue to plant birch even though it harbors BLM. Heavy losses will continue in suburban plantings.

2. Specific impacts -- expected changes in yield per acre (vegetation, primarily timber, recreation, wildlife) over the next decade due to damage by this complex of pests)

There will be an unknown loss in yield per acre due to BLM and BBB over the next decade. No loss assessments have ever been made.

VI. Control Response(s)

1. What actions could be taken to control this infestation or infection?

No infestation can be controlled. Individual owners can suppress a generation or two of BLM by treating trees with a systemic insecticide providing there are no addtional environmental stresses.

2. What triggers a decision to take action against a forest pest?

The homeowner decides trees have become unsightly and takes action. Forest values do not justify similar treatments.

3. What would happen if no action is taken?

The trees exposed to stress are vulnerable to BBB. Successful attacks further weaken and eventually kill the trees.

4. What could be done to prevent future infestations or infections?

Nothing, the infestations are here to stay.

VII. Technology Information

1. Describe the adequacy of available technology for prevention or reduction of infestations or infections.

There are no good strategies for prevention of BBB outbreaks. A market for birch would encourage use of some trees that are left standing and are later killed by BBB.

2. Describe technology needed to prevent, reduce, or control future occurrences of these infestations or infections.

Biological pesticides and parasites are needed to treat BLM in urban forests.

VIII. Treatment Options

1. Describe treatment techniques, accomplishments and costs

There is presently no treatment for the BBB. The BLM can be treated by a number of insecticides.

2. Technique (describe)

See VI, 1.

3. Cost of treatment

Cost per tree is about $3 if done by homeowner and $15 per tree if done professionally.

IX. Discuss the observed and expected trends of the next decade for this pest or complex of pests.

The trends are expected to continue at the present high level of infestation.

X. <u>In addition to the information required elsewhere in this outline, discuss the following:</u>

1. The obstacles, if any, to the use of existing technology for preventing outbreaks of the pest.

None, it's just that people don't like to use insecticides or are not aware of the conditions necessary to grow healthy birch.

2. The limitations placed on effective response to the pest by laws, policies of the Forest Service, and policies of other government (federal, state, local) agencies.

None.

XI. Recommendations

a. Further analysis needed.

None

b. Added information needed.

None

c. Actions needed now.

None

d. Actions needed within 5 years.

Develop an insecticide and application method for homeowner use.
Follow-up on Canadian attempts to release a parasite of BLM.

HYPOXYLON CANKER

I. Other Forest Pest or Forest Decline:

Hypoxylon canker, caused by Hypoxylon mammatum (Wahl.)Mill

II. Ecosystems and geographic "area covered" in this analysis:

Aspen type - Northeastern United States

III. Very brief history and biology of pest or group of pests:

1. Distribution

a. Description of host vegetation (preferred and secondary)

Preferred - Quaking aspen (Populus tremuloides Michx.)
Secondary - Bigtooth aspen (Populus grandidentata Michx.), and balsam poplar (P. balsamifera).

b. What percent of the Northeastern area is occupied by this host type

11.5%

2. Life cycle

Airborne spores enter host through wounds in living bark (usually broken branch stubs or breaks in bark), germinate to produce mycelium, and then invade surrounding tissue. The fungus can invade new tissue so rapidly, that callus tissue has no time to form. Cankers appear as slightly sunken, yellowish-orange areas, later progressing to an exposed mottled and crumbled cortex. Five to 14 months after infection, asexual spores are produced under blistered bark on condial "pillars." Three years after infection, sexual spores are produced on older portions of the canker. When fruiting bodies are wet, and bark temperature is above freeezing, the spores are forcibly discharged. Sporulation can occur for several years after tree death.

3. Cycles and triggers

Prevalence of hypoxylon canker varies without known reason from one geographical area to another, and also varies within a single area. High levels of infection occur in occasional "wave years" which may be associated with insect outbreaks and other tree wounding events.

4. How have man-caused changes in natural dynamics of the forest ecosystem influencing fire activity, ecosystem diversity, and nutrient cycling affected the incidence of pest outbreaks?

Disease incidence is not related to site quality, but severity is greater on poorer sites. Poorly stocked stands have a higher incidence of infection than well-stocked stands.

IV. Summarize the current status of this pest or group of pests.

1. Status of infestations or infection

Hypoxylon canker is currently the most important killing disease of aspen. The pathogen causes mortality in 3 to 7 years after bole infection. Presently, 1-2% of the aspen type is killed annually.

2. Percent of host type currently infested

The disease is prevalent throughout the Northeast and Great Lakes Region. Evidence of the disease can be found in almost all aspen stands. Percent of host type currently infested in the Lake States is 12 percent, which is a good estimate for the northeastern area since most of the aspen type occurs in the Lake States.

3. Acres infested

Acreages of infestation are difficult to estimate, but in Minnesota, where most of the aspen resource is found, 700,000 cords of aspen are lost annually due to mortality from Hypoxylon canker.

4. Probable course of the infestation or infection

a. When could an infestation or infection start?

It is agreed that tree wounding is necessary for infection. Therefore, any natural or human disturbance which leads to wounding of the cambium, could predispose trees to infection.

b. Where might it start?

Infection could occur in all age classes, in both dominant and suppressed trees. Canker incidence is inversely related to stand density, with infection greater along stand edges than within stands.

c. What are the expectations about future distribution and extent?

Because the mode of infection is not known, no future estimations about disease distribution and extent have been made.

d. Where will it be (area and cycle) in 1988, 1990, ten years?

Area - the disease will most likely maintain its present geographic range.
Extent - unknown due to the lack of knowledge about this disease.

5. What may have caused or triggered this infestation or infection?

a. Discuss both primary and secondary factors. (Specify not only the immediate biological causes but also the chain of events leading up

to those causes. Consider management decisions and cultural, economic, climatic and other events.)

It is an opportunistic fungus that has been a natural component of the forest environment for many years.

b. To what extent is aging of the nation's forests related to the incidence of this pest outbreak?

Aging has no effect on disease incidence, as hypoxylon canker is present in all age classes.

6. Describe the possible responses
   a. Acres treated by type of treatment

"Treatment" is impractical, but forest management alternatives are recommended and vary with disease incidence on a stand by stand basis.

b. Percent of total infested acres treated

None.

V. Describe the expected accumulative impacts associated with this pest or complex of pests.

1. General impacts

Unhealthy aspen reproduction, and economic impacts due to volume losses. Wildlife impacts - infection causes small openings that increase deer browse species.

2. Specific impacts -- expected changes in yield per acre (vegetation, primarily timber, recreation, wildlife) over the next decade due to damage by this complex of pests)

Reduction in aspen harvest due to this disease is 21 cubic feet per acre or 300 million cubic feet for the aspen type as a whole (in the Lake States). Economic impact is concentrated in Michigan and Wisconsin, where little excess of annual growth over anticipated harvest is expected in the future. There, harvest losses due to hypoxylon canker are large - 4.4 million dollars per year at the time of harvest.

Recreation impact - most infection is scattered and in small patches, and doesn't alter the general aethetics of an area, or decrease recreational opportunities.

VI. Control Response(s)

1. What actions could be taken to control this infestation or infection?

No direct control measures for Hypoxylon canker are known.

2. What triggers a decision to take action against a forest pest?

The amount of disease in a given aspen stand will trigger action. Stands greater than 25 percent infected should be harvested early, and converted to another genotype since susceptibility varies by clone. Lightly infected stands can be managed on longer rotations.

3. What would happen if no action is taken?

Infected trees are more subject to invasion by decay fungi, which also makes them more susceptible to windthrow at an early age. Therefore, if no action is taken in severely infected stands, losses can be expected via other biotic and abiotic agents. Inoculum load may persist/increase when infection levels remain high in the forest.

4. What could be done to prevent future infestations or infections?

Determine the mode of infection of this disease, which in turn would allow rates of infection to be predicted, and suitable management alternatives to be practiced.

VII. Technology Information

1. Describe the adequacy of available technology for prevention or reduction of infestations or infections.

Our present knowledge of this disease will allow for little prevention of hypoxylon canker, but reduction of infection can take place through forest management activities.

2. Describe technology needed to prevent, reduce, or control future occurrences of these infestations or infections.

-Increase our knowledge of the disease cycle
-Identify specific conditions required for infection and how they relate to insect activity and other unknowns.
-What role do environmental factors play in disease development, and whether these can be manipulated to reduce infection and/or disease development.
-Identify genetically resistant aspen clones.

VIII. Treatment Options

1. Describe treatment techniques, accomplishments and costs

Treatment techniques include harvesting heavily infected stands, and possibly thinning in very lightly infected stands. Accomplishments - ensuring healthy aspen reproduction, while getting maximum utilization of forest products prior to eventual deterioration of the stand. Costs of harvesting and/or thinning will vary dramatically according to tree size, stems/acre, and area treated.

2. Technique (describe)

Aforementioned

3. Cost of treatment

Aforementioned

XI. Recommendations

a. Further analysis needed.

Refer to sec. VII. 2.

b. Added information needed.

Forest inventory data could contribute additional knowledge about this disease over a broad geographical range and trends over time. If there were a separate entry for presence/absence of this disease per tree entry we could get a better estimate of its frequency of occurence. We would also be able to evaluate relationships between hypoxylon, stand and ecological factors, thereby helping to predict the course of the disease as well as improve management.

JACK PINE BUDWORM

II. Ecosystems and geographic "area covered" in this analysis: Jack and red pine forest type in the Lake States (Michigan, Minnesota, and Wisconsin).

III. Very brief history and biology of pest or group of pests:

1. Distribution.

a. Description of host vegetation (preferred and secondary): *Pinus banksiana* and *Pinus resinosa* are the preferred hosts. *Pinus sylvestris* is a secondary host.

b. What percent of the Northeastern area is occupied by this host type?

7.1 percent or 3,268,600 out of 45,944,000 acres of commercial forest land in the Lake States is occupied by this host type (red-jack pine). Of the 7.1 percent of host type, 58 percent is jack pine and 42 percent is red pine.

2. Life cycle.

Jack pine budworm was recognized as a subspecies of spruce budworm and described as a new species by Freeman in 1953. Depending on locality and weather conditions, the adults emerge from late June to early August. They mate and females lay their eggs in clusters of about 40 in two or three rows on the flat side of a pine needle. The eggs hatch in seven to ten days and the young larvae spin silken cases called hibernacula under bark and cone scales. The larvae molt without feeding through second instar within the hibernacula where they overwinter. In the spring they emerge and begin feeding on the pollen of staminate flowers. Soon the larvae migrate to new foliage and begin to feed. The needles are not consumed entirely, but are usually clipped off at the base and webbed together. Pupation occurs among the needles or between webbed shoots.

3. Cycles and triggers.

Marked increases in jack pine budworm populations have been associated with three primary factors: 1. Weather 2. Staminate flower production 3. Stand characteristics. Several successive years of above average winter temperatures and warm, dry springs, result in reduced mortality thus favoring population increases. Population fluctuations have been correlated with staminate flower abundance. Its believed that the pollen produced by staminate flowers has a nutritional advantage over foliage, and may also provide a more favorable microclimate which enhances larval survival. Stands in which populations

build up and are likely to suffer heavy defoliations are characterized by a predominance of trees that produce large numbers of staminate flowers. Such stands are typically overstocked, mature or overmature, growing on poor sites, and are mainly composed of poor vigor trees.

Typically jack pine budworm outbreaks last 2-3 years. The effects of weather, increased spring and fall dispersal losses, reduced staminate flower production and to a lesser extent, parasites and predators all contribute to the eventual population collapse.

4. How have man-caused changes in natural dynamics of the forest ecosystem influencing fire-activity, ecosystem diversity, and nutrient cycling affected the incidence of pest outbreaks?

The practice of monoculture in some areas, planting large acreages to jack pine has increased the risks of a jack pine budworm outbreak. Many of the poorer sites in the Lake States were planted with jack pine seedlings during the CCC days. This, in addition to fire protection and poor jack pine markets has led to abundance of mature and overmature stands of jack pine. Stress associated with older trees leads to the production of staminate flowers increasing the risks of a jack pine budworm outbreak.

IV. Summarize the current status of this pest or group of pests.

1. Status of infestations or infection: Due to the cyclic nature of this pest, populations continue to rise and fall each year in the Lake States area. The infested area in Michigan's Lower Peninsula declined in 1986 to 24,000 acres from the 600,000 reported in 1984. However, the infestation in Michigan's Upper Peninsula has increased from the 1,200 acres reported in 1986.

In central Minnesota the budworm populations have increased from 45,000 acres reported in 1985 to over 132,000 acres in 1986. In northeastern Minnesota populations collapsed from 200,000 acres reported in 1985 to less than 14,000 acres in 1986.

Wisconsin budworm population collapsed completely in 1986 when no observable defoliation was evident. The last infestation in Wisconsin had peaked in 1984 when over 130,000 acres were defoliated.

2. Percent of host type currently infested. Approximately 5-10% of the host type in the Lake States Area.

3. Acres infested - Approximately 175,000.

4. Probable course of the infestation or infection:

a. When could an infestation or infection start. When weather and staminate flower production favor the survival and development of the insect, particularly in those areas with abundant hosts in the mature to overmature age classes.

b. Where might it start? Anywhere the host type is found in the Lake State. Infestations have developed throughout the range of jack pine.

c. What are the expectations about future distribution and extent? Jack pine throughout its range, infestations have developed outside of the Lake State area, e.g. Nebraska.

d. Where will it be (area and cycle in 1988, 1990, ten years? In the Lake States the cycle is down significantly from the early 1980's when nearly 1,000,000 acres were infested. Because of the abundance of host type planted in the 1930's and 40's now reaching maturity, the cycle will probably start to repeat by the early 1990's.

5. What may have caused or triggered this infestation or infection?

a. Discuss both primary and secondary factors. (Specify not only the immediate biological causes but also the chain of events leading up to those other events. Consider management decisions and cultural, economic, climate and other events).

Describe the expected accumulation impacts associated with this pest or complex of pests:

1. General impact: Approximately 0.5-1.0 cord/acre of growth and mortality are lost annually for every acre infested. In 1981, Michigan had 551,000 acres of defoliation. They estimated volume and value losses probably exceeded 3.5 million dollars for over 356,000 cords of standing timber. The value of this timber delivered at the mill was estimated to be 27.2 million dollars.

2. Specific impacts: expected changes in yield per acre (vegetation, primarily timber, recreation, wildlife) over the next decade due to damage by this complex of pests. Immediate impacts caused by defoliation include mortality, top-killing, growth loss, and reduced pollen production. In Minnesota, outbreaks have caused mortality of up to 1/3 of the merchantable volume of jack pine stands and 90 percent mortality of intermediate and suppressed trees. Top killing of jack pine is common after outbreaks. Between 5-20 percent of merchantable trees may become stag-headed as a result of defoliation by the jack pine budworm. Tree growth may be considerably reduced, radial growth loss may be as high as one hundred percent. Impacts on wildlife habitat can be significant, affecting species like the Kirtland Warbler in Michigan. The loss of trees in recreation sites can adversely impact the use of these sites during and after an outbreak. The majority of jack pine acreage in the Lake States is mature and overmature trees, thus the next decade could see a substantial loss of volume due to budworm defoliation.

VI. Control Responses

1. What actions could be taken to control this infestation or infection?

Anticipate outbreaks of jack pine budworm and implement cutting practices to remove jack pines that most commonly produce staminate flowers (e.g. mature and overmature trees). Manage stands to promote fully stocked stands and encourage species suited to the site.

2. What triggers a decision to take action against a forest pest?

Market conditions generally have the greatest impact on management strategy. If markets are favorable, the action strategies discussed in question #1 above are often implemented.

3. What would happen if no action is taken?

The dollar loss associated with trees occupying a site for 40+ years will be whatever the market price for jack pine will command at the time. The loss of growth and reproduction will result both in dollar and productivity decreases.

4. What could be done to prevent future infestations or infections?

Reduce the amount of jack pine acreage proportional to projected future market trends. Maintain fully stocked stands and promote species diversity wherever feasible. Develop markets to reduce the amount of currently available old growth.

VII. <u>Technology Information</u>

1. Describe the adequacy of available technology for prevention or reduction of infestations or infections.

Knowledge to predict population increases or decreases is not very reliable. Few attempts have been made to predict jack pine budworm damage.

2. Describe technology needed to prevent, reduce, or control future occurrences of these infestations or infections.

Number 1 described above, and a willingness to undertake the proper steps to reduce the amount of mature and overmature jack pine. Markets need to be developed to utilize the over-abundance of host material. Silvicultural guidelines to reduce the impact of future outbreaks should be refined and transferred to the land managers who can use them.

VIII. Describe treatment techniques, accomplishments, and costs.

1. a. Monitor status of the insect populations.

b. Reduce the proportion of large blocks of host material.

c. Manage jack pine to ensure fully stocked stands.

d. Employ cutting practices designed to remove host material which produce an abundance of staminat flowers.

e. Salvage.

f. Encourage species suited to the site.

g. Insecticide treatments.

2. Technique (describe): Insecticide treatments using B.t. has been effective and environmentally safe.

3. Cost of treatment: B.t. treatment applied from an aircraft costs between \$15-\$20/acre.

IX. Discuss the observed and expected trends of the next decade for this pest or complex of pests. This was discussed previously in Section IV.

X. In addition to the information required elsewhere in the outline, discuss the following.

1. The obstacles, if any, to the use of existing technology for preventing outbreaks of the pest.
   a. Resistance to the use of insecticides (biological and chemical) to control the insect.

   b. Developing markets so the tremendous volume of excess timber currently on the stump can be utilized.
   c. Developing a pheromone that effectively captures adult males, the data from which can be used to predict populations trends.

2. The limitaitons placed on effective response to the pest by laws, policies of the Forest Service, and policies of the government (federal, state, local) agencies. None.

3. Other perceived questions:
   a. To what extent do forest plans and the NFS planning process address forest pests and forest health? Depends on the Forest, although each respective Forst solicited our input on the Forest nPlan, some incorporated our comments

others did not. With respect to the planning process, some Forests consider forest pest management alternatives and others virtually ignore them. If supervisors office personnel responsibe for implementing forest pest management initiatives are interested in FPM strategies, then they are often applied throughout the Forest.

b. How does the publics knowledge of forest ecology and forest management influence decisions affecting forest health? The publics lack of knowledge certainly can have an impact on forest health. Pressure applied by special interest groups on public land managers can influence their decisions regarding certain FPM initatives (e.g. opposition to clearcuts in order to salvage timber).

c. How has the increased public involvement in the forest management decision making process affected forest health? Its helped in some instances and hindered in others. The public has generated increased pressure on public officials to address foest health issues such as acid rain, gypsy moth, southern pine beetle, etc. On the other hand, it can impede progress or the development of pest management initiatives because of its lack of knowledge of pest management concepts.

d. How have public perceptions about pest-caused damages, losses, value of losses, cost of treatment or prevention, and risks of treatment affected forest health? Too often our decisions in these areas are influenced by a select few. In most cases thay have a misunderstanding or a skewed perspective of how the above issues should be addressed. Insecticide treatments, even when they involve biological insecticides are often appealed by special interests. Even when a package has been put together that is economically sound, environmentally safe, and benefits the majority these groups have demonstrated that they are capable of influencing the outcome and negating the prudent pest management approach.

e. How has forest landownership class affected forest health? Do the frequency and intensity of outbreaks by this pest vary by land ownership? What factors explain this difference? The majority (>50 percent) of jack pine acreage is

owned by public agencies, however most of the acreage

e. (con't) owned by private individuals or miscellaneous private organizations has jack pine in the upper age classes. There are two problems with this: 1) Most of the jack pine acreage is found in large blocks in certain areas of each of the Lake States. Thus, you have a virtual monoculture inviting forest pest problems. 2) Since much of the timber owned by private sources is in the upper age classes an effort by public land managing agencies to remove the old growth is required. If not, they will have an abundance of dead timber caused by jack pine budworm and flooded markets to handle the surplus volume.

XI. Recommendation

a. Further analysis needed.

Market analysis.

b. Added information needed.

None.

c. Actions needed now.

Develop markets and cut high-risk stands.

d. Actions needed in five years.

Much harvesting of mature and overmature timber.

MAPLE DECLINES

II. Ecosystems and geographic "area covered" in this analysis:

NORTHEASTERN UNITED STATES

III. Very brief history and biology of pest or group of pests:

1. Distribution

a. Description of host vegetation

Sugar maple is common in sugar maple-beech-yellow birch, black cherry-sugar maple, red spruce-sugar maple-beech, and beech-sugar maple cover types. Red maple is a major species in gray birch-red maple, and black ash-American elm-red maple.

b. What percent of the Northeastern area is occupied by this host type

The total gross acreage of the maple type is estimated at about 30 million acres, comprising about 20 percent of the forest cover type.

2. Maple decline events cycle

The cycle of events may be described as a premortality period consisting of a stress being applied to the forest. The trees respond by reduced growth. With additional stress branch dieback and mortality occurs. Elimination of stress may result in tree recovery. Continuation of the stress or addition of other stresses leads to dieback, decline and tree mortality. Even without additional stress, a chain of events may have been triggered that leads to death of most trees in the stand.

Insect defoliators and drought may provide the initial stress. These may be severe enough to cause declines on poorer sites or in weak stands. Stem and root diseases are promoted in stressed stands and eventually cause tree mortality.

3. Cycles and triggers

Drought, defoliation, stand disturbances and trunk, root and branch damaging insects and diseases are usually involved. Frequently the damage events are not well documented and consequently when declines occur the history of the damage events preceding the decline are fuzzy.

4. How have man-caused changes in natural dynamics of the forest ecosystem influencing fire activity, ecosystem diversity, and nutrient cycling affected the incidence of pest outbreaks?

Many of the original prime maple forests were converted to farm land. Most of the remaining maple forests were logged at least once, and frequently several times. Much of the logging removed the best and left the poorest trees and species. Thus some genetic change as well as forest composition changes may have occurred. Although some logging is continuing, in general, the maple forests are growing faster than they are utilized, and as a result the forests are getting older.

IV. Current status of maple declines

1. Status

Maple declines have occurred somewhere in the northeastern U.S. during most of the past decades. In the 1980's, maple declines are reported from Massachusetts, New York, New Hampshire, Pennsylvania, Vermont and Wisconsin.

2. Percent of host type currently affected

The proportion of the maple type with above normal mortality is probably less than 5 percent. The major problem is the lack of survey information describing the extent and the intensity of mortality in the stands.

3. Acres affected

About 1 million acres of maple is reported to have above normal mortality. In addition, several million acres in New York, New Hampshire, Massachusetts, Pennsylvania and Vermont have an outbreak of a pear thrips and several species of leaf and twig scales. Bruce spanworm outbreaks are occurring in Wisconsin and Michigan.

4. Probable course of maple declines

The forest tent caterpillar, saddled prominent and Bruce's spanworm may be in outbreak status within the next decade. At present a pear thrips and aphids are causing concern. Very little is known about their epidemiology and impact. Some observations suggest maple decline as one of the consequences.

a. When could a maple decline begin

New declines could develop in any areas where declines are not now present and where defoliator outbreaks develop. If atmospheric pollution is a major cause, then new areas of decline could occur in the higher deposition areas.

b. Where might it start?

Defoliator outbreaks are likely to occur along the northern tier of States. The Lake States, New York and Vermont sustained a rather severe drought in early part of 1987 summer, which could trigger insect outbreaks as well as direct declines.

c. What are the expectations about future distribution and extent?

The increasing maturity of the hardwood forests and the probability of major defoliator outbreaks suggest maple declines will increase in the near future. These increases are likely throughout the range of maple.

d. Where will it be (area and cycle) in 1988, 1990, ten years?

Droughts in the Lake States, New York and Vermont may trigger some additional declines in those areas as well as intensify declines already in progress. We can be reasonably sure that defoliator outbreaks will occur in the next 10 years followed by maple declines.

5. What may have caused or triggered current maple declines

a. Discuss both primary and secondary factors. (Specify not only the immediate biological causes but also the chain of events leading up to those causes. Consider management decisions and cultural, economic, climatic and other events.)

Most of the present declines probably were triggered by insect defoliation. Diseases such as sapstreak and armillaria may contribute to decline in the early stages, and are common in later stages. The causes of some of the declines are not known. Atmospheric deposition is suspected as a stress factor, but cause-effect relationships have not been established.

b. To what extent is aging of the nation's forests related to the incidence of maple declines

The hardwood forest are becoming older and more susceptible to biological stresses, and more vulnerable when stresses occur. Our knowledge of insect and disease problems is based on young forests. The consequences of stress in older forests need to be determined. On the basis of the knowledge that we have for short lived species, formerly minor pests become major, and stands formerly resistant to damage become vulnerable. Although sugar maple is believed to be long lived as a tree species, we do not know for sure if the rate of tree mortality is likely to increase because of stand maturity.

6. Describe the possible responses

a. Acres treated by type of treatment

Insect defoliation may be prevented with pesticide intervention. In the past small, high value areas have been treated to prevent damage. Maple declines

as discussed here have been subtle and unexpected, so no direct treatments have been used. Control methods for pear thrips and scale/aphids are not available and no one is working on them.

b. Percent of total decline area treated

Less than 1 percent of the maple forests have ever received insecticide treatments to reduce defoliation. Most of the treatments have been in sugarbushes and around homes for aesthetic purposes.

V. Describe the expected accumulative impacts associated with maple declines

1. General impacts

Locally, decline impacts may be severe. As much as 100% of the upper canopy trees may die. In addition, tree quality may be reduced due to branch mortality and decay even when the crown conditions seem to return to normal. Partial stand mortality could eliminate a stand from future commercial considerations. The impacts from pear thrips and scale/aphids are not known.

2. Specific impacts -- expected changes in yield per acre (vegetation, primarily timber, recreation, wildlife) over the next decade due to damage by this complex of pests.

Maple declines are likely to reduce the growth and productivity of the maple stand in the decline area. However, northeast-wide, forest survey data indicate that maple growth and quality is increasing faster than it is being harvested. Therfore, declines are not causing losses in the northeast as a whole. Individuals stands may be affected severely.

VI. Control Response(s)

1. What actions could be taken to control the current maple declines

The only approach available is to prevent damage to reduce unacceptable losses. This can be achieved by insecticide treatments in high value stands.

2. What triggers a decision to take action against a forest pest?

Perceived unacceptable losses caused by a pest usually trigger actions against that pest. Timber values and sugar production determine whether a stand is treated or not. The most common action is the attempt to salvage as much as possible.

3. What would happen if no action is taken?

The present condition may be considered as the consequence of no control actions being taken. The consequences of the present pear thrips damage and maple aphid/scale defoliation is not known.

4. What could be done to prevent future maple declines

Neither forest defoliator outbreaks nor adverse weather can be prevented. Therefore, reduction of the vulnerability of trees after they have been damaged is the only logical option. As a rule, keeping trees in a vigorous condition is the best overall option.

VII. Technology Information

1. Describe the adequacy of available technology for prevention or reduction of maple declines

Defoliator population control methods are available. Insect populations and the amount of damage to forests cannot be predicted. Very little information is available on the pear thrips and scale/aphid. Minimal effort is spent by research on most hardwood forest insects. The expected normal longevity of maple trees and stands is not known. It is not certain that the declines that we see today are abnormal. Certainly similar declines have occurred for many decades.

2. Describe technology needed to prevent, reduce, or control future occurrences of maple declines

Silvicultural options to maintain stand vigor should be evaluated to determine effectiveness in preventing losses when stands are subjected to stress caused declines. These methods can be implemented as needed.

VIII. Treatment Options

1. Describe treatment techniques, accomplishments and costs

Most of the defoliator damage may be reduced with aerial treatments of insecticides. Both chemical and biological insecticides are available. The esTimated cost for large area treatment is about $10 to $15 per acre. The success of the treatments usually depend on the quality of the pesticide application and the pesticide used. No control methods are available for pear thrips and scale/aphids.

2. Technique (describe)

Aerial application of insecticide using by fixed or rotary wing aircraft.

3. Cost of treatment

Estimated at $10 to $15 per acre for 1000 acre or larger projects.

IX. Observed and expected trends of the next decade for maple declines

Increased occurrence of declines must be expected because of the high probability of insect defoliator outbreaks, aging of the hardwood forest, the suspected impact of atmospheric pollution, and periodic droughts. The pear thrips and scale/aphid outbreak is expected to continue for several years.

X. <u>In addition to the information required elsewhere in this outline, discuss the following:</u>

1. The obstacles, if any, to the use of existing technology for preventing maple declines

As indicated earlier, large area protection from defoliators is possible, but the cost does not seem to justify the values protected. Localized high value stands occasionally are sprayed. Here again, the private landowners do not seem to have sufficient technical knowledge to make protection decisions. Most governmental agencies hesitate to encourage pesticide treatments, because of the public's perception of harmful effects of pesticides. Many of the state agencies are poorly staffed to provide pesticide control assistance. Federal support for "Other Forest Pests" suppression has been practically nil during the last decade. Other obstacles include the lack of a tracking system for documenting outbreaks (GIS), high cost of survey to locate declines, and lack of a system to predict when and where maple declines will occur.

2. The limitations placed on effective response to the pest by laws, policies of the Forest Service, and policies of other government (federal, state, local) agencies.

The administrative constraints are such, that it takes several years to reach a decision point to treat a pest. By that time most of the significant damage may be realized. Integrated forest management plans are non-existent or not effective. Each outbreak is treated as an unexpected surprise event.

OAK DECLINE

II. Ecosystems and Geographic Area Covered: Oak forests throughout the eastern United States

III. History and Biology:

Oak decline is a term used to describe a gradual reduction in vigor and subsequent dieback and mortality of individual trees in oak stands. Decline is most commonly observed in red (*Quercus rubra*), scarlet (*Q. coccinea*), pin (*Q. palustris*), black (*Q. velutina*), white (*Q. alba*) and chestnut (*Q. prinus*) oaks. The cause of death is usually *Armillaria mellea*, (shoestring root rot) or *Agrilus bilineatus* (two lined chestnut borer), but the decline can be triggered by any of a number of environmental stresses. Insect defoliation, frost, drought, waterlogging and mechanical injury from human activity cause a weakening of tree condition and the inability of the tree to resist attacks by normally secondary pests. Oak decline can therefore occur anywhere that oak occurs and has been subjected to any of these stresses.

Symptoms of oak decline include a gradual dying of branch tips, chlorotic, sparse and dwarfed foliage, and epicormic branching. Aborting of leaves and death of branch tips are "economizing" measures on the part of the tree to better utilize reduced food reserves caused by the stress, and result in slowed growth.

The mechanism by which trees are weakened varies with the specific stress, but ultimately a depletion of food reserves, and thus the vigor of the tree, predispose it to attacks by secondary organisms. For example, when a tree is defoliated more than about 60%, or is frost damaged, it will respond by refoliating, or putting out a second set of leaves in the same growing season. This process uses up stored starch which is normally reserved for refoliation the following spring. Two or three successive years of defoliation seriously weakens a once healthy tree, and is even worse for trees previously stressed by drought, thinning activities, or other mechanical injuries. Residual trees normally favored in thinning activities, i.e. those with large healthy crowns, are also vulnerable because of the energy required to replace a large mass of foliage. Another interesting sidelight is that the conversion of starch reserves to sugars for use by the tree provides an excellent medium for the growth of *Armillaria mellea*.

Decline and mass mortality of oak has been reported since the early 1900's, usually in conjunction with frost, drought or defoliation. Symptoms occurring in certain species of oaks with other species being relatively unaffected indicates preferential feeding by insects. Occurrence on certain sites, such as ridge tops or creek bottoms points to drought or frost as the primary stress factor.

There are about 50 million acres of oak-hickory type in the northern forest. About half, or 25 million acres, has damage currently from oak decline.

IV. Current Status:

Because oak decline results from any number of stresses, it can occur anywhere at any time rather than in cyclical outbreaks. In recent history, oak decline has been most noticeable following defoliation by gypsy moth and the oak leaf tier/roller complex in the northeast. Acreage figures are difficult to ascertain but it may be safe to assume that a good portion of the "mortality" following forest insect outbreaks results from this chain of events. Death of trees normally occurs from 2 to 5 years following peak defoliation and can be as high as 90-98% on poor rocky sites. In the near future oak decline will be most noticable at the advancing front of the gypsy moth infestation, where any severe outbreak of oak defoliating insects occur, and anywhere else that stress conditions become severe enough.

At present, there exists in the eastern United States an extensive oak forest, much of which was established near the turn of the century due to human activity. Regrowth of abandoned farmland, extensive clearcutting for charcoal production, overgrazing and other human activities produced an artificially uniform growth of oak of roughly the same age. This condition is conducive to outbreaks of pests, and may account in part for the apparent increase in pest problems in recent years.

V. Short Term Impacts:

In recent years large scale occurences of oak decline have caused a glut in the supply of oak in localized areas as landownwers rush to salvage dead and dying timber. If the highest quality managed oak stands are not protected, then there may follow a shortage of quality logs.

VI. Control Responses:

Currently there is no practical treatment for the control of either shoestring root rot or two lined chestnut borer. In order to minimize the impact of oak decline we must concentrate on avoiding the stresses that lead to attacks by these organisms. An obvious measure is to prevent defoliation by such insects as gypsy moth and the oak leaf roller/tier complex discussed elsewhere in this report. Exceptionally high value oak stands (for timber, wildlife or recreation) and those recently thinned should be emphasized for protection, as it is impractical, and probably not ecologically desirable, to treat all of the area threatened by infestations.

While it is impossible to control drought and frost, proper silvicultural treatments and favoring of oaks only on proper sites can help maintain healthy oak stands. Where these stresses do occur, foresters should note their occurrence and be prepared to salvage mortality before significant value is lost.

VII. Technology

Currently, research is being conducted to find a practical treatment for *Armillaria mellea*. An operationally stump treatment to slow its spread

through the soil following salvage and thinning operations could possibly lessen the impact of this root rot.

Control efforts aimed at wood boring beetles such as the two-lined chestnut borer are expensive and generally not practical for large scale control.

VII. Treatment Options:

It remains to be seen how costly and effective stump treatments will be against Armillaria root rot if these are developed.

IX. Long Term Trends:

Sites where oak is growing outside of its ideal conditions in the future should begin to revert to more mixed species giving rise to more climax types of forests such as northern hardwoods. This could occur through natural forest succession and forestry practices characterized by partial cuttings and lack of burning. Certainly outbreaks of forest pests and other stress agents leading to oak decline will accelerate forest succession. While the loss of valuable oak timber is unfortunate, a more mixed and natural distribution of species and ages should make the eastern forests more resistant to future pest outbreaks.

X. Additional Considerations

There are no practical means of directly preventing oak decline because it occurs sporadically over such a large geographical region. Only indirectly through more intensive forest management can oak decline be reduced. This involves the commitment of federal funding for suppression of forest insect outbreaks. Contingencies for all forest pest management actions need to be developed and included in forest planning which involves public review of all proposed actions. A public better educated as to the consequences of pest outbreaks and the factors leading to oak decline would be better able to provide meaningful comments.

Landownership only influences oak decline to the extent that the oak forest type is more likely to be removed on private and industrial woodlands and maintained on public lands to perpetuate a varied mix of tree species with oak as a source of high valued timber products and wildlife mast food.

XI. Recommendations

We do not believe that there is either the need for further analysis nor additional information needed to manage the oak decline. The actions needed to manage the decline involve action to prevent defoliation through aerial insecticide application where needed to protect the resource at greatest risk.

THE NATIVE OAK LEAFTIERS AND ROLLERS SPECIES COMPLEX

I. Ecosystems and Geographic Area Covered in this Analysis

The oak forests throughout the Northeastern and Northcentral United States.

II. Indentity, Biology and Life Histories of the Oak Leaftiers and Rollers

Identification of Species

Oak leaftiers and oak leafrollers are native lepidopterous defoliators which affect most of the oak species found in the northern hardwood forests. Most species belong to the family Tortricidae, but moths in five other families are also involved. The most important of the oak leaftiers is *Croesia semipurpurana* (Kearfott) while the most abundant oak leafroller is *Archips semiferanus* (Walker). Other species of leafrollers such as *Archips argyrospilius* (Walker) and *Choristoneura fractivittana* (Clem.), as well as the fall cankerworm *Alsophila pometaria*, may also feed in complex with *A. semiferanus* and *C. semipurpurana*.

Host Vegetation

The oak leaftier attacks mainly trees in the red oak species group, with other oaks being secondary hosts, while the oak leafroller concentrates on white oak species group trees along ridges. Apple and witch hazel are secondary hosts of the oak leafroller. Both species are widely distributed through the eastern United States and are often found in association during outbreaks. Prior to the spread of the gypsy moth, these two native moths were the most important defoliators of oak in most areas of the northeast. Susceptible forest types comprise about 41% of the commercial timberland or 30% of the total area in the eastern United States.

Life Cycle and Damage

Both species overwinter as eggs which hatch in late April or early May. The oak leaftier has a short larval stage. Its eggs which were laid individually on smaller branches and twigs in June and July, hatch just before budbreak of its host. The larvae will mine unopened buds before they consume the expanded leaves. Oak leafroller usually hatches a week later. The oak leaftier binds two or more leaves together with silk and feeds between them, while leafrollers fold one leaf and bind it with a web. Oak leafrollers have a longer feeding period, pupating in late June after undergoing 5 instars. Adults emerge in July and lay eggs in flat oval masses about 3/16" in diameter on the trunks and lateral branches of host trees. Pupation for both species takes place in the litter or on the ground.

Outbreak Cycles and Causes

The history of outbreaks by these two native defoliators and their complexes is difficult to trace due to lack of general knowledge and apparent confusion as to their exact identity in past reports. More recent references usually indicate a complex of the two species with other moths, which may be more accurate, and is at least a simplifying assumption.

The first outbreak was reported in the USFS 1959 Forest Insect Conditions Report which mentioned severe defoliation in southwestern Massachusetts, northwestern Connecticut and New York. The pest causing the damage was called a "Leaf-roller", but the scientific name and host species indicate that is was in fact the oak leaftier.

The next outbreak referenced was in 1964, which was the beginning of a major epidemic in the northeast. From 1964 to 1972, Pennsylvania reported from 500,000 to 1,000,000 acres per year defoliated with less defoliation in 1973 and 1974. By 1975, native oak defoliator populations had apparently declined to endemic levels. Other states most hard hit were West Virginia (up to 200,000 acres per year defoliated until 1976), New Jersey and Michigan. Virginia reported smaller amounts of defoliation, Wisconsin had mortality on 12,500 acres in 1973. The years 1977-1981 appear to have been relatively quiet with a slight buildup occurring in Pennsylvania, 21,000 acres reported on the Allgeheny National Forest in 1982 and 23,000 acres reported state wide in 1983. Recent heavy gypsy moth activity in Pennsylvania may have masked or distracted from the effects of some other defoliators.

Influence of Man-caused Changes on Susceptible Forests

Recent severe epidemics of native oak defoliators, such as oak leaf rollers/tiers and fall cankerworm, are most likely attributed to the maturing of pure, even-aged stands of oaks established in the late 1800's and early 1900's. The high component of oak in these forests resulted from excessive cutting, overgrazing by domestic livestock and wild-fires. This unbroken and abundant food source may allow usually endemic populations of native defoliators to reach the high populations and severe damage experienced in recent years.

IV. Summary of the Current Status of this Pest Complex

Outbreaks of the oak leaftier/roller complex currently occur only in western Massachusetts where 350,000 acres experienced some noticeable defoliation in 1985. This outbreak may spread westward into New York and Pennsylvania during the next several years, possibly developing into the large-scale infestation which covered much of this same area during the 1960's. It is also probable that the influence of these native defoliators may be somewhat lessened by the presence of the gypsy moth when this introduced defoliator is at outbreak population densities in the same forested area.

The cause of the current increase in oak leaftier/roller populations probably lies in the general drought conditions which have existed in the southern New England States during the early 1980's. Drought is known to influence food quality of oaks and small changes in the quantities of nutrients within the leaves of host trees can have a major influence on the growth, survival and fecundity of herbivorous insects. The continued

abundance of mature oak stands within the forests of this region undoubtedly will contribute toward raising the probabilities that another outbreak will develop with dramatic consequences to the oak resources. However, there is little likelihood that any future outbreaks of this native oak defoliator complex will bring about direct suppression through aerial application of insecticides, even though this method is the most effective and economical one available.

V. Forest Impacts of this Pest Complex

During the past thirty years, these native oak defoliators have been recognized as having a primary role in the decline and mortality of oaks in the Northeast and Northcentral US. Scattered but severe population outbreaks of these defoliators have been reported from Connecticut, Massachusetts, New York, New Jersey, Pennsylvania, West Virginia and Michigan.

A 1975 report from the Pennsylvania Bureau of Forestry estimated losses over 900,000 acres of 2.5 billion board feet of timber and 700 million cubic feet of pulpwood with a (1975) dollar loss of $100 million. About 100,000 acres experienced 90-98% oak mortality. For many of the State Forest affected, timber management of green stands was virtually nonexistent. With major efforts at salvaging the dead and dying oaks, market were quickly saturated and much of the standing dead oaks was left to rot in the forest.

VI. Control Response

Reduction of the risk of another outbreak of the oak leaftier/roller outbreak through more intensive management of the oak forests of the region involves the development and implementation of cutting practices which drastically alter the species and size classes presently in the oak forests. Many of these practices center on clear-cutting to promoted the less shade tolerant, early successional species such as maples, ash, cherry, and yellow poplar. The dependence placed on oak timber for the export market and on oak trees for wildlife mast production have placed oak trees in a very sacrosanct position in the policies of many state and federal management agencies. Few mature trees would be cut for fear to loosing them as a source of wildlife mast food.

More direct action against the oak leaftier/rollers would seem warranted to reduce their influence on the oak forest. However, only in local forested areas would it be feasible operationally or economical the spray outbreaks of these pests. The consequences of spot treatments would be the natural development and completion of the population outbreak cycle over most of the area.

VII. Technology Information

Most of the information currently available is barely adequate to conduct surveys which monitor the populations of the moths which are part of this complex, and predict their damage. Most often, the first hint of the presence of these moths lies with the occurence of their damage. Therefore, measures which might be taken to prevent their damage are difficult to implement. Such measures should center on silvicutural actions which would reduce the susceptiblity and hazard of oak stands and on direct suppression in the

building year(s) of an outbreak. Unfortunately, much of the knowlege needed to carry out such action is limited because only minimal emphasis has been placed on the basic and applied research needed to understand these native defoliators and manage them effectively.

VII. Treatment Options

During an outbreak, only direct suppression of its populations through aerial application of insecticides would be effective and economical at reducing populations below the damaging densities. During the last major outbreak in Pennsylvania, the only registered insecticide, carbaryl formulated as Sevin-4-Oil, was aerially applied at 1 quart per acre with very successful results. The current cost of this product applied from a helicopter is about $10 per acre.

IX. Expected Trends

During the next decade, the complex of native oak leaf tier/rollers in expected to have an increasing influence in the oak forests of the Northeast and Northcentral United States if the past is any reflection. The damage from the complex will be greatest where the gypsy moth remains at endemic densities, although both groups of insects may work together in an area.

X. Additional Considerations for Managing the Complex

Obstacles to using existing technology for survey, prediction, and prevention of outbreaks of this complex of native oak defoliators lie with the failure of most managers to recognize the damage which these insects are capable of causing.

There have been limitations on the use of federal funding for research and application into these native defoliators compared with the funds available to counter the threat posed by such introduced forest pests as the gypsy moth.

The NFS forest plans only address this complex in general terms and consider actions to reduce damage on an as-needed-basis with no provision for prevention through incorporation of any such practices into daily management. Forest plans which were developed with too many details are viewed as being too inflexible and restraining by managers when they try to implement new technology which becomes available. Because only limited details of forest pest management often were available to those preparing a plan and to the public which reviewed it, many perceive this as encompassing the entire scope of knowledge on forest pest management and are unwilling to consider changes to the plan. The public, in general, does not always understand the influence which forest pests have on forest health, damage, losses and economics unless there is a direct confrontation between the forest pest and an individual over some forest resource.

In summary, the detail necessary to conduct meaningful forest pest management is left out of plans to avoid public contraversy concerning 1. the use of pesticides, 2. accelerated harvest of susceptible trees, including the need for clearcutting, and 3. to enable forest managers to exercise more flexible response and professional judgement in dealing with pest outbreaks. In doing so the forest manager has severely restricted the options available to respond

to outbreaks precisely because they were not addressed in forest plans and has served to maintain or enhance the vulnerability of forests to damage from forest pests.

Landownership probably has had its greatest effect on the forest health issue by placing large areas of public ownership in a quasi-natural condition with expectations on the part of the public and land managers that it will always be that way. They chose to ignore the presence of forest pests, whether native or not, and expect the status quo to remain. Management is expected to eliminate or reduce change when change is inevitable. More highly managed forests such, as those owned by industry, may have less frequent and intense outbreaks because direct suppression with insecticides in a timely manner is less restrained by public involvement and bureaucracy.

XI. Recommendations

We do not believe that there is either the need for further analysis nor additional information needed to manage this complex of oak leaftiers/rollers. The actions needed to manage the complex involve surveying for the defoliation and planning suppression through aerial insecticide application where needed to protect the resource at greatest risk.

SAPSTREAK DISEASE AND DECAY

II. Ecosystems and geographic "area covered" in this analysis:

Excluding aspen-birch, all other types in the northern forest with special emphasis on the maple-beech-birch type.

III. Very brief history and biology of pest or group of pests:

1. Distribution
   a. Description of host vegetation (preferred and secondary)

All conifers and hardwoods are susceptible to decay albeit to differing degrees. Sugar maple (*Acer saccharum*) is the host for *Ceratocystis coerulescens*, the cause of sapstreak disease.

   b. What percent of the Northeastern area is occupied by this host type

About 89% of the northern forest is non-aspen type, of which 22% is maple-beech-birch.

2. Life cycle

Decays are wound related diseases. The most common causes of wounds in old-growth forests were fire, cankers, broken or dead tops and branch scars. Logging induced injury to the stem, base and roots of trees is the most important source of wounds in managed forests. Numerous microorganisms are transmitted to wound sites usually by wind or insects. Following successful invasion of host tissue, the tree compartmentalizes the infection.

The extent of decay in non-heartwood forming trees generally is restricted to the amount of wood present at the time of wounding. In heartwood forming trees, the decay column will extend farther along the heartwood-sapwood boundary. Multiple wounds over time are therfore more important in causing losses due to decay than are multiple wounds at any one time. Wounds to larger trees result in greater volume lost to decay since more wood is present at the time of wounding. Also, logging wounds are usually concentrated on the lower bole where the greatest volume and value is located. As the tree ages, external stress factors cause the balance of energy to shift from the tree to disease organisms. The compartmentalizing barriers formed by the tree eventually give way to the decay organisms.

Sapstreak is a vascular wilt disease of sugar maple. The fungus also is associated with root and basal wounds particularly in sugarbushes and partial cut areas along main haul and skid roads. A tree may die within 2-7 years following infection depending on additional external stresses.

3. Cycles and triggers

As mentioned, both diseases are wound related. Logging wounds are the most important factors leading to infection in managed forests. Increasingly, multiple entries into stands are required due to the greater emphasis on unevenage management, individual tree and group selection cutting, and increasing rotation lengths. Wounds are an inevitable consequence of logging activity and losses to decay and wound associated diseases will increase.

4. How have man-caused changes in natural dynamics of the forest ecosystem influencing fire activity, ecosystem diversity, and nutrient cycling affected the incidence of pest outbreaks?

Fire was once the greatest source of wounds. Fire control, cutting of old growth and shortening of rotation lengths, and evenage management are recognized as the preferred means of keeping decay losses to a minimum. As discussed in "3" above, the current trend will put forests at greater risk to loss from both decay and sapstreak.

IV. Summarize the current status of this pest or group of pests.

1. Status of infestations or infection

The percent cull due to decay increases with tree age, diameter, and number of basal wounds. Decay is present in all forest types. Generally, the northern forest is increasing in age and the percent cull can be expected to increase correspondingly.

2. Percent of host type currently infested

The percent of cull will vary between and within forest types, however all forests older than 40 years, or about 90% of the area, will have some loss due to decay.

Sapstreak disease has been reported in sugarbushes of New York, Vermont and Massachusettes, and in forests of Wisconsin and Michigan. The percent of host type known to be infected is less than 1%.

3. Acres infested

There are about 145,000 million acres of non-aspen type in the northern forest. An estimated 130,000 million acres is greater than 40 years, or has measureable decay.

4. Probable course of the infestation or infection
   a. When could an infestation or infection start?

Decay is an integral part of nutrient cycling in all ecosystems and can be found at anytime. Generally, measureable decay only affects trees older than 40 years.

Sapstreak disease is positively associated with root and basal wounds. Poor logging practices or logging during times of the year when trees are

particularly susceptible to wounding can result in infections. Fungal inoculum is ubiquitous and all wounds can potentially be infected.

b. Where might it start?

Decay might start in residual trees in stands that have recently been logged or have sustained other injuries.

Sapstreak can infect any root and basal wound on sugar maple. Repeated wounding increases the likelihood of infection. Trees in sugarbushes along major haul and skid roads are at higher risk, as are residual trees in stands that are being logged.

c. What are the expectations about future distribution and extent?

The future distribution of decay organisms will remain the same. The extent of loss will increase with age. Percent cull on a cubic foot basis ranges from 6.7% in trees 80 years of age to 34.7% at 210 years. Decay accounts for an estimated 16% of all standing hardwood volume, and 9% of softwood volume.

Increased surveillance will show an increase in the distribution of sapstreak. A real spread will also take place as cutting practices in sugar maple forests are implemented which favor the spread of this disease.

d. Where will it be (area and cycle) in 1988, 1990, ten years?

See the previous answer for decay. The known distribution of sapstreak in 1970 was several individual trees on the U.P. of Michigan (in addition to the original find in North Carolina). Seventeen years later it is known to be infecting forest trees in Wisconsin and sugarbushes in N.Y and New England. The fungus is a common sapstain of hardwood lumber, so under the right conditions, i.e wounds on sugar maple, it has the potential to become widely distributed throughout the range of the maple type..

5. What may have caused or triggered this infestation or infection?

a. Discuss both primary and secondary factors. (Specify not only the immediate biological causes but also the chain of events leading up to those causes. Consider management decisions and cultural, economic, climatic and other events.)

As mentioned earlier, wounds of any sort, particularly root and basal wounds, contribute the most to the incidence, severity and spread of both sapstreask and decay.

b. To what extent is aging of the nation's forests related to the incidence of this pest outbreak?

Aging contributes to the increased volume and value lost to both sapstreak and decay. Age is not an important factor per se in the incidence of these diseases; however, older trees may be at greater risk since they will have been exposed to more situations where wounding may have occurred.

6. Describe the possible responses

a. Acres treated by type of treatment

The only treatment is prvention since wounding occurs whenever commercial activity takes place. Minimizing the number and severity of wounds by concentrating skid and haul roads, using smaller, less destructive equipment, short log skidding, minimizing the number of entries, and close supervision of logging activities will reduce the incidence of these diseases. In the case of sugarbushes, the widespread adoption of tubing instead of using collection buckets reduces the number of entries into bushes and lessens the chance for wounding.

b. Percent of total infested acres treated

Not applicable.

V. Describe the expected accumulative impacts associated with this pest or complex of pests.

1. General impacts

It's estimated that up to 80% of volume lost to all causes is due to decay.

Sapstreak can kill trees that are current sap producers or would be future quality crop trees.

2. Specific impacts -- expected changes in yield per acre (vegetation, primarily timber, recreation, wildlife) over the next decade due to damage by this complex of pests)

Most northern forests were cleared for one reason or another during the last century. Today most forests are between 60-120 years old. The most consistant relationship that has been demonstrated in individual tree species and timber stands is that the number of trees with decay and the volume of decay increases with age. About 6-20% of the presently available cubic foot volume is already affected by decay. This will not increase dramatically in the next decade but more indvidual trees will likely become infected and those already infected will lose an increasing percentage of volume to decay.

It is difficult to predict the increase in sapstreak over the next decade. If ever there was a disease that seemed to be tailor-made for the type of cutting practices being promoted these days, sapstreak is it. Recent surveys in partial cut northern hardwood stands indicate about 5% of trees wounded between 5-7 years ago are affected by sapstreak. Symptoms take up to 7 years to manifest themselves, therefore this would seem to be a realistic expectation of the impact of sapstreak in other similar stands.

VI. Control Response(s)

1. What actions could be taken to control this infestation or infection?

Both diseases can be "controlled" by reducing wounds to roots and bases of trees, minimizing the number of entries and shortening rotations.

2. What triggers a decision to take action against a forest pest?

Probably the perception that in the long term, poor practices today will result in lost value tomorrow.

3. What would happen if no action is taken?

The number of trees and volume lost will continue to increase.

4. What could be done to prevent future infestations or infections?

Discussed previously.

VII. Technology Information

1. Describe the adequacy of available technology for prevention or reduction of infestations or infections.

The current technology is sufficient to minimize the incidence and spread of sapstreak and decay. What is lacking is the recognition of their importance and the potential increase in that importance due to current management practices.

2. Describe technology needed to prevent, reduce, or control future occurrences of these infestations or infections.

Previously discussed.

VIII. Treatment Options

1. Describe treatment techniques, accomplishments and costs

Not applicable.

2. Technique (describe)

Not applicable.

3. Cost of treatment

Not applicable.

IX. Discuss the observed and expected trends of the next decade for this pest or complex of pests.

See V.2--Specific impacts.

X. In addition to the information required elsewhere in this outline, discuss the following:

1. The obstacles, if any, to the use of existing technology for preventing outbreaks of the pest.

The primary obstacles to use of existing technology are, 1. Forest management plans that call for increased rotation lengths and unevenage management, 2. Conversely, the public perception that cleacutting is bad, 3. More mechanized

logging with large equipment which causes increased wounding to residual trees.

2. The limitations placed on effective response to the pest by laws, policies of the Forest Service, and policies of other government (federal, state, local) agencies.

Forest management plans that limit management options and that in fact make forests more vulnerable to decay and sapstreak.

XI. Recommendations

a. Further analysis needed.

No further analysis about causes and effects or controls are needed.

b. Added information needed.

Survey information on the incidence of sapstreak. Individual managers need to know if they can expect significant losses prior to the next scheduled entries

c. Actions needed now.

Recognition of the long term impact of these diseases.

d. Actions needed within 5 years.

Sapstreak surveys and information on specific impacts on a stand basis.

SARATOGA SPITTLEBUG

I. Other Forest Pest or Forest Decline: Saratoga spittlebug (SSB)

II. Ecosystems and geographic "area covered" in this analysis:

The ecosystem and areas involved are the northern pine forests of the United States and southern Canada as far west as Manitoba.

III. Very brief history and biology of pest or group of pests:

1. Distribution
   a. Description of host vegetation (preferred and secondary)

   Primary hosts of the Saratoga spittlebug are young red pines in plantations. However, it also occurs to a lesser extent in young plantations of jack pine or mixed red and jack pine, and occasionally, they attack white pine.

   b. What percent of the Northeastern area is occupied by this host type?

   This host type comprises approximately 7 percent of the commercial forest type of the Northeastern area.
2. Life cycle

   The SSB overwinters in the egg stage beneath bud scales of red pine or in needle sheaths of jack pine. Nymphs begin emerging in late April to early May about the time red pine shoot elongation begins to occur. The nymphs rapidly move from the pine trees to suitable alternate hosts. The list of alternate host plants is extensive. With the exception of grasses, sedges, lichens, and mosses, most other plants will support SSB nymphal development. Early instars develop well on herbaceous plants such as orange hawkweed, goldenrod, everlasting, and wild lettuce. Later instars prefer the small stems of a variety of woody plants such a willows, brambles, blueberries, and sweetfern. However, the relative abundance of sweetfern in a given plantation is a key factor in determining SSB risk. The higher the percentage of sweetfern, the higher the risk that SSB populations will reach damaging levels. Nymphal development continues until late June or early July when adults begin to appear. The newly emerged adults fly to the pine hosts to begin feeding and to mate. Egg laying reaches a peak about 2 to 3 weeks later. Adults are present and feeding until late September or until the first killing frost.

3. Cycles and triggers

The SSB does not appear to be a routinely cyclic insect. Population flare-ups are triggered by factors that enhance survival of the emergent nymphs. An abundance of the preferred alternate hosts such as brambles, willows, and sweetfern provide an ideal environment for populations to build in. There are many interacting environmental factors such as egg parasites, nymphal predators, adult parasites and predators, and several weather related factors that exert control on SSB populations. When these are lacking, an outbreak may follow. The greatest population control is probably exerted by weather related factors such as abnormally hot, dry, windy spring weather which causes desiecation of early nymphal stages or late spring frosts shortly after nymphal emergence.

4. How have man-caused changes in natural dynamics of the forest ecosystem influencing fire activity, ecosystem diversity, and nutrient cycling affected the incidence of pest outbreaks?

The greatest man-caused changes in the natural dynamics of this pest are probably related to ecosystem diversity. As more and more red pine plantations were established, often on sites with considerable sweetfern that would have been better left to some other tree species, conditions for the SSB became increasingly favorable for outbreaks.

IV. Summarize the current status of this pest or group of pests.

1. Status of infestations or infection

SSB populations are always at outbreak levels somewhere in the Lake States. Maine, New York, and Pennsylvania have also recorded problems, although to a lesser degree. SSB outbreaks are not often as widespread and as spectacular as bark beetle or defoliator outbreaks. However, unlike most defoliator outbreaks that cause growth loss and possibly some tree mortality, an SSB outbreak that goes unchecked will usually destroy the plantation.

2. Percent of host type currently infested

It is estimated that essentially all the host type is currently infested, though not all at damaging levels.

3. Acres infested

There are approximately 11.5 million acres of pine in the Northern forests and of this, about 1.7 million acres occurs in the Lake States, Maine, New York, and Pennsylvania. Of that figure, about 26 percent or 431,000 acres contain trees within the size range normally damaged by the SSB. Approximately half of that, or 216,000 acres, could be moderate to high risk.

4. Probable course of the infestation or infection

a. When could an infestation or infection start?

Spittlebug activity is very difficult to predict, but this pest is widely distributed so population can build rapidly when conditions are favorable. This occurs continually in scattered locations throughout the Lake States.

b. Where might it start?

Although SSB populations can, and often do, errupt in plantations with a variety alternate host plants, plantations with a heavy ground cover of sweetfern are at highest risk and are the most likely candidates for an outbreak.

c. What are the expectations about future distribution and extent?

The future distribution and relative abundance of SSB problems can be related to red pine planting programs in the Northeastern area. There is a positive correlation between the abundance of yound red pine plantations in the suitable tree size range and the occurrence of SSB outbreaks. If red pine planting programs fall off in the future, so will SSB problems.

d. Where will it be (area and cycle) in 1988, 1990, ten years?

It is not likely that the distribution and severity of the problem in 1988 and 1990 will differ significantly from the current situation.

5. What may have caused or triggered this infestation or infection?

a. Discuss both primary and secondary factors. (Specify not only the immediate biological causes but also the chain of events leading up to those causes. Consider management decisions and cultural, economic, climatic and other events.)

The primary factors contributing to, or causing, the current SSB outbreaks are difficult to specifically identify but are probably related to the lack of parasites, predators, or the presence of favorable climatic conditions.

However, certain management decisions and cultural practices, have most certainly contributed to the outbreaks. Many red pine plantations have been established on very high risk sites where sweetfern, willows, brambles and other preferred alternate hosts are abundant.

In addition, stand survival inspections, stand certification, and subsequent compartment examinations do no provide an adequate level of surveillance during the period of time when the stands are most vulnerable. At a minimum, inspections of high risk stands at 2 year intervals would be desireable until closure occurs and the risk of SSB damage no longer exists.

Instead, if seedling survival is good,a stand may be certified as established a year or two after planting and might not be revisited until the next compartment examination, possibly nine or ten years later. In the meantime, the stand has grown into its most susceptible size range and could be destroyed by the SSB.

b. To what extent is aging of the nation's forests related to the incidence of this pest outbreak?

Aging of the nation's forests is not a factor with the SSB

6. Describe the possible responses

a. Acres treated by type of treatment
b. Percent of total infested acres treated

The most logical approach to SSB management is to avoid planting red pine on high risk sites and to use herbicides to destroy the alternate host plants in the establish plantations having unacceptably high risk ratings. A well applied herbicide treatment removes the alternate hosts and provides the benefits of release from competition at the same time. Up to 10 percent of the susceptible host type, or about 43,000 acres could be candidate for treatment. That figure could be reduced considerably by intensive surveys by FPM and by resource managers attempting to include high risk sites into their routine release schedule.

V. Describe the expected accumulative impacts associated with this pest or complex of pests.

1. General impacts

General impacts of SSB outbreaks include reduced stand vigor, growth loss, form loss, dieback, and tree mortality. Additional site preparation and replanting become necessary as plantations fail because of SSB caused damage.

2. Specific impacts -- expected changes in yield per acre (vegetation, primarily timber, recreation, wildlife) over the next decade due to damage by this complex of pests)

Impact information accumulated over the last seven years in the Lake States indicates that up to 20 percent of the moderate and high risk red pine plantations will be lost or suffer severe damage from SSB outbreaks. That involves about 43,000 acres

(Total susceptible red pine = 431 K acres; moderate and high risk about half of that or 216 K acres; damaged or lost about 20 percent of that or 43 K acres) areawide and that is probably a conservative figure as the red pine plantations distributed in other Northeastern states have not been considered.

The dollar value associated with the severe damage or loss of 43,000 acres of red pine could approach $13 million. That figure is based on a conservative cost estimate of $300 per acre for site preparation, planting stock, and labor costs for planting and does not take into consideration the loss of between 5 and 10 years of growth.

No significant changes in the level of SSB activity is anticipated in the next decade.

VI. Control Response(s)

1. What actions could be taken to control this infestation or infection?

   Depending on the severity and length of the outbreaks, two treatment options could be considered: 1) In particularly active situations, chemical insecticides could be employed to reduce adult SSB populations. 2) If outbreaks are detected early, time may be available to use herbicides to remove the alternate hosts and thus the SSB populations. This would be the preferred alternative if damage levels were such that another year of adult SSB populations could be tolerated. The use of herbicides does not provide the rapid reduction of SSB population that chemical insecticides do.

2. What triggers a decision to take action against a forest pest?

   The decision to apply a chemical insecticide is normally triggered by the detection of severe SSB feeding damage in the form of branch flagging or dieback and tree mortality.

   If an outbreak infestation is detected earlier through some form of stand examination involving scar counts, then the resource manager may opt to apply an herbicide to the alternative hosts.

3. What would happen if no action is taken?

   If the outbreak is severe and lasts for 2 to 3 seasons, plantation failure is the usual result if no action is taken. In addition, plantation failure often occurs even when insecticides are applied because the injury necessary to produce the symptoms of flagging and dieback is so severe that the trees cannot recover. In the case of early detection when an herbicide treatment could be used, failure to treat could result in plantation failure also but the time period would be up to 3 years longer. Spittlebug caused injury is cummulative so depending on population levels, it can take from 2 to 5 years for tree mortality to begin occurring.

4. What could be done to prevent future infestations or infections?

Future infestations are best prevented through an integrated approach to management utilizing planting site risk rating, appropriate tree species selection, accelerated surveillance, the use of herbicides to remove alternate host plants, and the limited application of insecticides when necessary.

VII. <u>Technology Information</u>

1. Describe the adequacy of available technology for prevention or reduction of infestations or infections.

Adequate technology exists to prevent or reduce the occurrence of SSB outbreaks. However, current technology is somewhat labor intensive, particularly if resource managers are involved in a large red pine planting program. Because of this, surveillance is often overlooked.

2. Describe technology needed to prevent, reduce, or control future occurrences of these infestations or infections.

Refinement of predictive technology would help to reduce the amount of time spent in surveillance of high risk plantations. Current risk rating technology can tell us where problems may occur, but refinement of that technology could help us to narrow the scope of our detection and surveillance activities.

VIII. <u>Treatment Options</u>

1. Describe treatment techniques, accomplishments and costs

There are essentially two treatment options currently available: insecticidal treatment of the adult SSB populations, or herbicidal treatment of the alternate host plants in the affected plantation.

2. Technique (describe)

Malathion is normally the insecticide of choice and is applied either aerially or from the ground, depending on the size of the outbreak area and constraints to ground application imposed by site factors in the plantation.

Herbicidal treatment of the alternate host is usually accomplished with hexazinone or glyphosate. Velpar L, Pronone 10G, or Roundup are the chemicals generally used.

3. Cost of treatment

The cost of an insecticide treatment is about $15 per acre. The cost of an herbicide application varies from about $40 to $85 per acre depending on whether aerial or ground application is used. Lower costs and more uniform coverage are generally realized when aerial application is used.

IX. Discuss the observed and expected trends of the next decade for this pest or complex of pests.

SSB populations appear to randomly flare up and later subside throughout the Lake States and occasionally in Maine, Pennsylvania, and New York. Outbreaks are almost always associated with plantations on sites having an abundance of alternate hosts, particularly sweetfern. Outbreaks will continue to occur in this pattern for the next decade unless significant changes in the level of surveillance, coupled with rapid response, can prevent outbreaks.

Barring any changes in current surveillance intensity, only marked increases or decreases in red pine planting programs could affect the probability of SSB outbreaks in future decades.

X. In addition to the information required elsewhere in this outline, discuss the following:

1. The obstacles, if any, to the use of existing technology for preventing outbreaks of the pest.

The most significant obstacle to the use of existing technology is the availability of labor and/or NFS's current system of plantation examination, certification, and subsequent compartment examination.

Generally, plantations are at their highest level of risk when they are between the ages of 4 to 10 years old. During that period the trees have grown to the size that is desirable to support SSB populations, the stands are nowhere near closure, and alternate host plants have become reestablished since their removal during site preparation. It is also during this time when the plantations are least likely to be visited on a routine basis. After the trees are planted, they are checked for survival at one and two years. I survival is good at that point, the stand may be certified as established and free to grow and might not be examined again until the next scheduled compartment exam. That could be as much as 9 to 10 years later. If the plantation is out of the way and off the "beaten path", outbreak populations may develop and go undetected until it is too late to do anything about it. It is because of this, that some system of interim inspections or surveillance is necessary. Accelerated surveillance however, is labor intensive.

2. The limitations placed on effective response to the pest by laws, policies of the Forest Service, and policies of other government (federal, state, local) agencies.

There are no limitations to effective response imposed by FS (or any other) laws or policies. However, decisions to not fund SSB prevention projects in the Lake states has created concern at the Forest level. In some cases, Districts have too many high risk

red pine plantations, some that are in real need of herbicide treatment, to assimilate them into their annual release program. When SSB prevention projects are not funded, some of the plantations must go without release because it is fiscally impossible to handle all the plantations. This concern can be ameliorated over time as IPM of the SSB gradually reduces the number of red pine plantations established on high risk sites. However, the lack of prevention funds is presently creating a real hardship for some Districts.

The other concern, one that is shared by FPM, relates to the question of credibility. The Forests are continually advised of their responsibilities to reduce losses and to manage insect and disease pests. They are also counseled on the merits of IPM and the importance of practicing it. Then when attempts are made to exercise their responsibilities, the funding (usually relatively small amounts by national standards) is denied in favor of the gypsy moth or some other "major" pest. Often we find out later that suppression monies from those programs were turned back.

It is difficult for the FPM field offices to convince the Forests of the importance of forest insect and disease management when this occurs.

3. Other Perceived questions:

a. To what extent do forest plans and the NFS planning process address forest pests and forest health?

b. How does the public's knowledge of forest ecology and forest management influence decisions affecting forest health?

c. How has the increased public involvement in the forest management decision-making process affected forest health?

d. How have public perceptions about pest-caused damages, losses, value of losses, cost of treatment or prevention, and risks of treatment affected forest health?

e. How has forest landownership class affected forest health? Do the frequency and intensity of outbreaks by this pest vary by land ownership? What factors explain this difference?

The Forest planning process, the publics' knowledge of forest management, increased public involvement, public perceptions of SSB management or control, or forest land ownership patters do not substantially influence or affect our ability to manage SSB.

XI. Recommendations

a. Further analysis needed.
b. Added information needed.
c. Actions needed now.
d. Actions needed within 5 years.

Three things could help to improve our management of the SSB:

1. Research leading to improved predictive techniques would help managers focus their attention on the highest risk plantations and decrease the cost of young plantation surveillance.

2. A committment by the Forests/Districts to increased surveillance on moderate and high risk red pine plantations would help reduce losses to the SSB until improved predictive technology can be developed.

3. Favorable consideration of SSB prevention projects would help the Districts to get a handle on the problem while working towards a more "SSB free" environment using the other components of the IPM program.

FOREST TENT CATERPILLAR

I. Other Forest Pest or Forest Decline: Forest Tent Caterpillar (*Malacosoma disstria* Hubner

II. Ecosystems and geographic "area covered" in this analysis:
Geographic area and Ecosystems covered in this report - Aspen, Aspen-Birch-Conifer types in New England, Mid-Atlantic, Lake States, and Central States.

III. Very brief history and biology of pest or group of pests:

1. Distribution
Forest Tent Caterpillar (FTC) is a native insect which is an early spring defoliator
   a. Description of host vegetation (preferred and secondary)
   Prefers aspen leaves, but eats all hardwood leaves except red maple.
   b. What percent of the Northeastern area is occupied by this host type
   12 percent of commercial forest in NA (20 million acres) is covered by preferred host type
2. Life cycle
FTC overwinters in masses of 150 to 350 eggs. Eggs hatch at bud break and feed gregariously on leaves for 6 to 7 weeks (5 instars). Larvae have a crepuscular feeding habit, congregating during the day on tree trunks. During late instar larvae find pupation sites which may be in rolled leaves, on buildings, or other manufactured articles. They emerge as moths in late June to early July, disperse, mate and lay eggs on host twigs.
3. Cycles and triggers
There are about 14 years between low and outbreak population levels. FTC remains in outbreak for 2 to 6 years in any given stand. The outbreak is favored by abundant hosts; cold, moist winters; cool, dry springs.
4. How have man-caused changes in natural dynamics of the forest ecosystem influencing fire activity, ecosystem diversity, and nutrient cycling affected the incidence of pest outbreaks?
Man-caused changes have had little to no influence on incidence of FTC outbreaks.

IV. Summarize the current status of this pest or group of pests.

1. Status of infestations or infection
Status- About 350,000 acres received moderate to heavy defoliation in 1987.
2. Percent of host type currently infested
About 0.2% of the host type is currently in outbreak.
3. Acres infested

About 350,000 acres are in outbreak.

4. Probable course of the infestation or infection
   There will always be an outbreak of 50,000 to 20,000,00 acres in NA every year in the host type.
   - a. When could an infestation or infection start?
     There are always substantial outbreaks of the FTC somewhere in the Northeast, Canada,northern MN, or ME.
   - b. No change is expected in future distribution and/or extent of the infestation.
   - c. What are the expectations about future distribution and extent?
     In 1988, there will probably be 200,000 acres of outbreaks in the northern Lake States and another 10,000 acres in NY, VT, and ME. 1990 will be about the same situation. In 1997, FTC will be in outbreak status somewhere in the northern Lake States.
   - d. Where will it be (area and cycle) in 1988, 1990, ten years?
     In 1988, there will probably be 200,000 acres of outbreaks in the northern Lake States and another 10,000 acres in NY, VT, and ME. In 1990 the situation will be about the same. In 1997, FTC will be in outbreak status somewhere in the northern Lake States.

5. What may have caused or triggered this infestation or infection?
   The previously mentioned environmental factors were conducive to FTC populations.
   - a. Discuss both primary and secondary factors. (Specify not only the immediate biological causes but also the chain of events leading up to those causes. Consider management decisions and cultural, economic, climatic and other events.)

     Outbreaks occur following moist and cold winters which permit survival of eggs. The absence of cold rains or glaze storms after hatch allows survival of first instar larvae. Dry spring weather prevents an epizootic of virus so that larvae survive. An abundance of host foliage provides energy for the caterpillars. Parasites and predators, chiefly a flesh fly, provide control of low FTC populations.

     Harvesting of aspen prevents an outbreak. Aspen is a pioneer species that is a climax type on 10 million acres in the Lake States and an intermediate type on 10 million acres in other parts of NA. Aspen is regenerated by sprouts from roots in clearcut stands. Spruce, red maple, and birch invade these stands and form the understory.

     In the Lake States, as few as 40 aspen per acre, when clearcut, will produce a new stand of sprout origin aspen of 2,000 stems per acre. At 40 years of age, this stand will produce about 25 cords of pulpwood at a value of of nearly $2 per cord. The perpetuation of aspen due to clearcutting of old stands means ther will continue to be outbreaks of FTC.

     In the New England States and NY, aspen is found in small stands and is a result of fires and clearcutting (for farms and other uses). These stands usually convert to other forest types after aspen dies of old age diseases and storms.

b. To what extent is aging of the nation's forests related to the incidence of this pest outbreak?

Age of trees has little effect on FTC attack. However, saplings and seedlings are not conducive to oviposition by the FTC female.

6. Describe the possible responses

a. Acres treated by type of treatment

Aspen is not treated to control FTC because it is not economically feasible. B.t at 4 to 8 BIU/acre will effectively reduce FTC populations.

b. Percent of total infested acres treated

About 1 percent of outbreak area was treated in 1987. Usually there is no spraying to control this pest.

V. Describe the expected accumulative impacts associated with this pest or complex of pests.

1. General impacts

It has an impact on residents of forest areas where the outbreaks occur. Also, the flesh flies which are parasitic on the FTC create a nuisance in these areas.

2. Specific impacts -- expected changes in yield per acre (vegetation, primarily timber, recreation, wildlife) over the next decade due to damage by this complex of pests)

Overall, there will be little change in the availability or production of aspen due to FTC. Individual stands may suffer 60 to 90 percent reduction in growth, and some 10 to 50 percent tree mortality, but there is expected to be a surplus of aspen in the next decade.

VI. Control Response(s)

1. What actions could be taken to control this infestation or infection?

Actions - The options available are to clearcut stands of aspen where FTC is in outbreak or treat outbreaks with one of several registered insecticides. Aerial spraying with B.t. at 4 to 8 BIUs/acre is effective in preventing defoliation. Ground application using a mist blower or hydraulic sprayer containing chemical insecticide or B.t. been effective in urban forests.

2. What triggers a decision to take action against a forest pest?

A recreation or some special use area will trigger concern and possibly action.

3. What would happen if no action is taken?

The FTC will eventually die down to endemic levels for about 14 years. Some trees would die and the majority of trees would return to full growth rate in 3 years without ever making up the lost growth.

4. What could be done to prevent future infestations or infections?

Nothing, the FTC is here to stay.

VII. Technology Information

1. Describe the adequacy of available technology for prevention or reduction of infestations or infections.

A pheromone that attracts male FTC moths is commercially available from Canada and is being pilot tested in New England. A virus that suppresses most FTC outbreaks is readily isolated and produced. However, it is not commercially available nor is it registered by EPA.

2. Describe technology needed to prevent, reduce, or control future occurrences of these infestations or infections.

We need early indication of incipient outbreaks and a virus that could be cheaply applied.

VIII. Treatment Options

1. Describe treatment techniques, accomplishments and costs

This is the same as VI.

2. Technique (describe)

Aerial or ground application of insecticides.

3. Cost of treatment

$15 to $20 per acre.

IX. Discuss the observed and expected trends of the next decade for this pest or complex of pests.

The expected trends are continuation of large outbreaks in the Lake States and small outbreaks throughout the rest of NA.

X. In addition to the information required elsewhere in this outline, discuss the following:

1. The obstacles, if any, to the use of existing technology for preventing outbreaks of the pest.

There are no existing technologies for preventing outbreaks of FTC.

2. The limitations placed on effective response to the pest by laws, policies of the Forest Service, and policies of other government (federal, state, local) agencies.

Too much time and money are expended to write an EIS or EA for aerial spraying a biological material such as B.t.
Most FS personnel know the public is spooked by the word "spray" and therefore hesitate to treat.

XI. Recommendations

a. Further analysis needed.
   None.
b. Added information needed.
   None
c. Actions needed now.
   Registration of the FTC virus to make it commercially available.
d. Action needed within 5 years.
   Same as c.

RED SPRUCE AND BALSAM FIR DECLINE

II. Geographic area covered in this analysis:
New England, New York and West Virginia

III. Brief History and Biology:

1. Distribution:

a. Description of the host vegetation: The spruce-fir forest type is comprised of spruce (mostly red spruce _Picea rubens_) and balsam fir (_Abies balsamea_. The spruce-fir forests occupy the shallow soils of the poorer sites on steep mountain slopes and also in the low elevation flats. The major stand types include spruce-fir swamp, spruce-fir flats, mixed spruce-hardwood, spruce-fir slope, old field spruce and high elevation balsam fir. The occurance of the spruce-fir type and the size of individual trees is dependent on elevation, latitude, parent soil material, and land form.

b. Area: There are over 11 million acres of spruce-fir forest type in the Northeastern Area, primarily occurring in areas of Maine, New Hampshire, Vermont, New York, western Massachusetts, and the mountains of West Virginia.

2. Life cycle:

More than one factor is involved in what has been described as spruce decline. The variety of organisms thought to be involved in the decline will be briefly described in Section IV. 5.

3. Cycles and Triggers:

Predisposing, inciting, and contributing factors to consider in relation to spruce-fir decline include: land use history of the site; historical and current status of insect and disease activity; and environmental and climatic influences.

Considering the land use history of these sites many disturbances have affected these stands including land clearing for agriculture, logging, fire, hurricanes, etc.. On the other hand, forest preservation is also a factor to be considered, especially in designated "wilderness" and "forever wild" areas.

Historically, there have been a variety of causes both biotic and abiotic that lead to decline symptoms on spruce and fir, specifically reduced growth and deteriorating crowns. The biotic factors which have lead to significant amounts of tree mortality in the past include defoliating insects, bark beetles, and root, stem, and branch diseases. Several of these organisms have been reported occurring at various times over the last 100 years creating a cycle of tree mortlity, regeneration, maturation, and then as the trees become overmature there is a resurgance in the pest population and significant tree mortality occurs once again. Many of the stands which are now exhiting decline symptoms and tree mortality are old stands where the incidence of various historically important pests has increased.

Abiotic factors such as drought, and wind, ice, and snow have also been historically important, especially at the higher elevations. Again, these factors may be more significant in older stands, thus contributing to the decline disease spiral. Phenomenon such as fir waves, caused by wind and

ice, are recognized as part of the natural cycle of balsam fir stands at the higher elevations.

Overall climatic and man-made environmental factors have been suggested as contributing to the current decline spiral. These hypotheses have yet to be adequately addressed.

4. How have man-made changes in natural dynamics of the forest ecosystem influencing fire activity, ecosystem diversity, and nutrient cycling affected the incidence of pest outbreaks?

Forests in the northeast were relatively undisturbed until the early 1600's. Before this time only natural phenomena such as hurricanes, fires, and insect outbreaks were the only events affecting the forests. Land clearing and commercial timber harvesting reduced forest land dramatically by the late 1800's. Then, as agricultural land was abandoned and timber land was purchased and protected by individual States and the Federal Government, overall forested land again increased to the proportions we see today. However, many of the areas of spruce and fir forests present before the European colonists arrived are today hardwood stands.

As mentioned previously, when vast areas of remaining timber land was protected from harvesting, such as was done in the Adirondacks in New York in the mid 1800's, this set the stage for the old age spruce-fir forests which occur in many areas today. And the overmature age of the stands sets the stage of insect and disease activity and break up of the stands.

IV. Current status of spruce-fir decline:

1.Status:

The present occurrance of red spruce and balsam fir mortality in the mountainous regions of the northeast has received a lot of publicity. Pockets of spruce and fir mortality have been reported occuring in portions of New Hampshire, Vermont, New York, western Maine, western Massachusettes, and West Virginia. Following the recent reports and suggestions that acid rain might be involved, land managers and the general public have become increasingly concerned about the red spruce and balsam fir resource.

2. Percent of host currently affected:

It appears that all areas of the spruce-fir type is affected to one degree or another, however the mortality occurs in pockets within the affected areas. Also, the extent of the mortality varies from state to state. The differences are probably related to stand age, soil, and elevation. (A large portion of the spruce-fir forest located in northern Maine, northern New Hampshire and northeastern Vermont has been recently infested and defoliated by the spruce budworm. These areas are not considered to be part of the area where spruce and fir decline from "unknown causes" is occurring.)

3. Acres affected

In response to public and landowner concerns Federal-State Cooperative surveys were conducted to determine the extent of damage in the affected areas. A survey was conducted in New Hamshire, Vermont and New York in 1984. Based on random sampling techniques, it was determined that mortality was occurring on over 300,000 acres in the three states. Also, in the heavy mortality areas there were about 15 standing dead spruce per acre. In general, the proportion of balsam fir rated as declining was less than that for spruce.

It was also determined that spruce regeneration stocking is the highest in the heavy mortality areas.

As an extention of the original survey, an aerial photography project was initiated in order to map all of the areas in New Hampshire, Vermont, New York and western Maine where spruce and fir mortality was occurring. This data, which will be summarized by the end of 1987, will provide acres of vegetation type in various mortality classes.

A survey was also conducted in West Virginia showing 1600 acres of heavy mortality.

4. Probable course of the infestation:

a. When did the decline start? It is documented that a substantial amount of mortality has occurred in various areas in the northeast. Reports of the most recent decline episode date back to the early 1960's. The mortality appears to be continuing. In order to determine the rate of mortality, permanent plots were established in the heavy mortality areas of New Hampshire, Vermont, New York, western Massachusetts, and West Virginia. These plots are remeasured each year and a preliminary report will be prepared in the fall of 1987.

b. Will the decline spread? and c. What are the expectations about the

future distribution and extent? and d. Where will it be (area and cycle) in future years?: In order to address these questions, the complete mortality mapping project in New York and northern New England is scheduled to be redone within 5 years of the original survey. This is to see if overall mortality is increasing within the affected areas and in the affected areas are increasing in size. Based on the annual data collected from the permanent plot, it appears that tree mortality is continuing, but not at a very rapid rate.

5. What may have caused or triggered this infestation or infection?:

a. Primary and secondary causes: There are many factors that are contributing to tree mortality and deterioration of the crowns. The historically important biotic agents (insects and diseases that have been reported as causing damage to forest trees in the past) and are present in the survey areas currently include:

1. Spruce beetle (Dendroctonus rufipennis)- Areas of New Hampshire and the Adirondacks in New York are currently infested. Preliminary results of a survey conducted in 1986 indicate that about two-thirds of the spruce (greater than 10" dbh), which were sampled in the Adirondacks in heavy mortality areas, were infested with the beetle. This organism has been know to cause extensive mortality in mature timber as far back as the early 1800's.

2. Eastern dwarf mistletoe (Arceuthobium pusillum)- Areas of New Hampshire, Vermont, and the Adirondacks in New York are currently infested. Preliminary results of data collected at the same time of the spruce beetle survey indicate that one-third of the trees sampled in the Adirondacks were infested with eastern dwarf mistletoe. As with the spruce beetle this organism has been know to cause extensive tree damage in the past.

3. Cytospora canker (Valsa kunzei)- This organism has been isolated from trees with deteriorating crowns in New Hampshire, New York, and West Virginia. The organism is considered an intregral component of the spruce ecosystem in West Virginia and its role the spruce forests of New York and northern New England has yet to be assessed.

4. Armillaria root rot (Armillaria sp.)- Root rots, especially Armillaria, as also important factors in the decline of spruce and fir. The research done to date indicates that Armillaria is an aggressive pathogen in conifers and can be readily found in areas of heavy mortality.

5. Stem rots- There are various stem rots which have been detected in affected stands, especially Fomes pini in spruce. This organism can be found in most areas surveyed.

6. Various other insects and diseases- There are many other organisms which can be found associated with dying and low vigor spruce and fir such as needlecast diseases, rust diseases, defoliating and sucking insects, etc. These occur in varying degrees in many stands throughout the affected area.

There are several abiotic factors which have been documented as contributing to the deteriorating spruce and fir crowns, especially at the higher elevations. These include the damage caused by wind, and ice and snow, which cause tip dieback, tufting, flag trees, etc. These factors are also know to cause the natural phenomenon of "fir waves", defined as a wave-like pattern of fir mortality and natural regeneration at the higher elevations.

It has been suggested that air pollutants, specifically acid rain, are contributing environmental factors to be considered in relation to spruce and fir decline. There is no data presently that supports this hypothesis.

b. To what extent is aging of the nation's forests related to the incidence of this decline? As was indicated earlier the areas that appear to be most affected, that is having the greatest mortality and the greatest proportion of trees with deteriorating crowns, are where some of the oldest stands are occuring, especially those which have been protected from harvesting or forest management over the last 150 years.

6. Describe the possible responses:

Since there is no one pest involved in this decline, but rather a long list of various biotic and abiotic factors acting individually or in conbination with one another, there is no prescribed treatment which would effectively "solve the problem" and end the tree decline and mortality.

V. Describe the expected accumulative impacts associated with this decline:

1. General impacts:

The impact on the overall spruce-fir resource appears to be significant. Recent reports of tree ring analysis show a consistant decline in the growth of red spruce occurrring since the early 1960's. In localized pockets, tree mortality continues, as well as branch dieback and mortality in live trees. Spruce decays slowly, therefore the appearance of the mortality on a specific mountain side may be dramatic since there are a number of standing dead trees.

2. Specific impacts:

The tree mortality is expected to continue in localized areas, especially in areas where spruce beetle, dwarf mistletoe, and root and stem diseases are present. Also, the deterioration of tree crowns in exposed sites at the higher elevations, is expected to continue. Therefore the overall "decline" of the spruce-fir resource is expected to continue. Since most of the mortality is occuring in noncommercial forest land (excluding the spruce budworm affected areas) the economic impacts may be low, but the impacts on aesthetics and public opinion will probably be high.

VI. Control responses:

1. What actions could be taken to control this decline?

Since all the the factors, mechanisms, and interactions are at this time unknown it is difficult to recommend specific actions to mitigate the decline or the effects of the decline on the resource. Even if these were known it would be very difficult to control the rate or spread of the decline, since there are no known economic or practical means to control most of the biotic and abiotic factors mentioned above. Control of the spruce beetle and eastern dwarf mistletoe is possible, but considering the size of the area affected, is probably impractical.

2. What triggers a decision to take action against a forest pest?

The issue of spruce decline is an excellent example of what influence public opinion and concern has on a forestry related issue. The many articles and interviews which appeared in the media over the last few years have sparked the massive research effort into determining the effects of atmospheric deposition on our nations forests.

3.What would happen if no action was taken?

See section 1 above.

4. What could be done to prevent future spruce-fir declines?

To prevent future spruce-fir declines a variety of influences must be considered: (a) the age of the forests, especially those which are protected and unmanaged; (b) the impact of insects and diseases; (c) the impact of climatic and weather factors; (d) the impact of air pollutants. To understand all of these influences separately and interactivly is a monumentsl task.

VII. Technology information:

1. Describe the adequacy or available technology for prevention or reduction of spruce-fir decline, and 2. Describe technology needed to prevent, reduce, or control future instances of spruce decline:

There is not enough information known about the biology of the biotic organisms which have been found affecting the spruce and fir. Specifically, the spruce beetle, dwarf mistletoe, and root and stem rots. More research is needed into the life cycle, symptom expression, impact, and survey techniques for these organisms. When the overall impact of these organisms on growth and tree vigor is assessed, then the influence of air pollution can be determined, providing the necessary technology is available.

VIII. Treatment options:

1. Describe treatment techniques, and 2. Describe costs:

There are no treatment techniques prescribed at this time which are feasable to implement, therefore costs cannot be addressed.

IX. Observed and expected trend of spruce-fir decline:

As mentioned previously the tree mortality is expected to continue in pockets throughout the range of spruce and fir. Permanent plots are in place to assess the rate of mortality in a specific area. A mortality mapping

project is underway to delineate the areas where mortality is occurrring as a baseline for future mapping projects to determine the extent and spread of the mortality.

X. Additional information:

1. Obstacles to the use of existing technology for preventing spruce decline:

As previosly mentioned the existing technology is limited or nonexistant for controling the individual pests found in association with dead and declining trees and this is the major obstacle. Also, even if there were contol or preventative methods described the logistics and cost of implementing the methods would be prohibitive.

2. Limitations placed on effective response to the decline by laws and policies of government agencies:

The State and Federal responce to the issue of spruce-fir decline has been dramatic in many ways. Substantial amounts of money and manpower has been spent on this problem in the past few years. This is different from usual operating procedures where is takes months or a year to implement a specific project. In that sense, these have been few limitations.

XI. Recommendations:

1. Further analysis needed:

The cause of spruce-fir decline is presently being addressed, but the answers are not really close at hand. As stated previously, there is a need to further assess the role of the identified insects and diseases and weather related injury in areas where tree mortality is occurring and tree crowns continue to deteriorate. Therefore, it is recommended that funds continue to be made available to conduct detection surveys and biological evaluations of the identified pests, and that funds are availble to research the biology of the identified pests and the determine if there are any as yet unidentified pests contributing to the decline. The cost/benefit of this research needs to be determined since most of the areas where the decline is occurring are in non-commercial forests. Is it the commercial landowner who will help determine if the research is justified or the general public as a whole, which to this point has been propelling the Forest Service response to spruce-fir decline? Also, much more research into the role of atmospheric deposition needs to be conducted, since at present we cannot attribute any particular symptom identified in spruce or fir trees directly to air pollutants.

2. Added information needed:

Additional information is needed concerning the vulnerability and susceptability of a particular stand to specific insect and disease pests. What are the comnponents which set the stage for break-up of a particular stand? And when the decline commences, what are the components which determine the rate at which the decline progresses?

3. Actions needed now:

Some of the activities presently underway to address this issue of spruce-decline include: (a) growth analysis; (b) symptom expression description; (c) dose-response studies; (d) insect and disease influences; (e) determination of the extent of the mortality; and (f) monitoring levels of

specific air pollutants. These actions need to continue, whether as part of the Spruce-Fir Research Cooperative, Forest Service Special Project, or State Survey. There appears to be a concerted effort to coordinate all these activites and to bring in professionals from all disciplines to join in the effort to explain the spruce-fir decline.

4. Actions needed 5 years from now:

The data being collected now will provide a baseline for future information. The information will describe the present condition of the spruce-fir resource and will provide a "snapshot" of one point in time in the "decline disease spiral". The data will need to be updated periodically to determine what the extent of the decline will be 5 or 10 years down the road, and to determine the overall status of biotic and abiotic stresses on the spruce-fir resource.

WHITE PINE WEEVIL

Pissodes strobi (Peck)

I. Identification

White Pine Weevil

II. Geographic Distribution of the Host

White pine weevil, a native species of North America, is distributed throughout the range of eastern white pine that extends from the Northeastern United States and Southeastern Canada, westward to the Great Lakes and southward to northern Georgia in the Appalachian Mountains.

III. History and Biology of the White Pine weevil

1. Distribution

a. Description of host vegetation

Eastern white pine is the most preferred host tree, but other conifers such as Norway spruce, jack pine, Scots pine, pitch pine, and red pine are also attacked.

b. What percent of the Northeastern area is occupied by white pine?

About 55 percent of the Northeastern area is occupied by white pine forest type. New Hampshire, Massachusetts, Vermont and Maine account for approximately 2.6 million acres of white pine type.

2. Life Cycle

Adults overwinter in pine litter near the base of host trees. On leaving the litter, they climb or fly to the vertical terminal shoot and feed on the inner bark tissue. Egg laying usually begins in the spring. Females may visit more than one leader to deposit her eggs. The egg hatch is five to ten days. The larvae feed at the junction of the bark and wood and destroy the cambium and inner bark tissues in their downward progress. As they mature, they tunnel into the wood and pupate in the pith. Others may pupate in shallow cavities chewed out in the surface of the wood. They emerge as adults from these cavities in ten to fifteen days. The adults feed on old and new branches

until cold weather forces them to hibernate. There is one generation a year.

3. Cycles and Triggers

The typical trend in weevil populations is a rapid build-up that alternates with more modest increases and sometimes temporary declines.

4. How have man-caused changes in natural dynamics of the forest ecosystem affected the incidence of pest outbreaks?

White pine weevil did not become a problem in eastern United States until the middle of the 19th century when fields cleared for agriculture were abandoned and were seeded in by white pine. These stands were poorly stocked, and the trees were repeatedly and severely weeviled. Added to the acreage of such poorly stocked new stands were the many acres of plantations established early in the twentieth tentury and provided abundant breeding sites for the insect. Also, when Scots pine and Norway spruce were introduced the in United States and was widely used in reforestation, these trees were subject to serious injuries by the weevil. With the introduction of these two introduced tree species, weevil populations reached new higher levels of infestation.

IV. Summary of the current status of white pine weevil:

1. Status of white pine weevil infestations in the Northeast.

In 1986, white pine weevil infestation intensities varied considerably in the Northeast.

In Maine, weevil damage to eastern white pine and jack pine appears to be heavier then expected.

In Vermont, the insect was a statewide problem in Christmas trees and ornamentals.

In New York, there was a significant increase in the population in 5 southeastern counties.

In Rhode Island, weevil infestations were moderate, but populations were down for the second consecutive year.

In Wisconsin, populations were stable or decreased slightly in the northwestern part of the state. Heavy infestations were found on sapling white pines in one county.

In Michigan, infestations are expected to be higher than in previous years for susceptible species. Jack pine is being severely damaged in Michigan.

In Minnesota, the insect attacked conifers in natural stands, plantations, and ornamental plantings. All host susceptible species were severely damaged by the insect. The insect is not a problem in the southern Appalachians.

2. Percent of host type currently infested, see (1) above.

3. Acres infested

   Except for Michigan and Vermont, most states did not report the number of acres infested.

   In 1986, Michigan reported about 23% of white pine seedlings and saplings were damaged, while Vermont reported less than 1%.

4. Probable course of the infestation.

   a. When could an infestation start?

      Unlike many insects that reach a peak in their populations, which is usually followed by a collapse, white pine weevil infestations depend on site and environmental conditions and other factors that fluctuate from year to year.

   b. Where might it start?

      Heavy infestations usually start in dominant and co-dominant pines growing in open areas because they are highly susceptible to weevil attacks.

   c. What are the expectations about future distribution and extent?

      Further distribution of the weevil infestation may not increase greatly because the demand of white pine has not increased. In the Northeast and Lake States through 1970 and early 1980's, pine has provided 20 percent or less of the softwood, roundwood and 10 percent or less of the total roundwood requirement. In New England, white pine is not in much demand at pulp and paper facilities. Since the market for white pine is down, less will be planted or managed for investment. Therefore the weevil will be less important.

   d. Where will it be in 1988, 1990, ten years?

      White pine weevil, a native species of North America, will always be a major pest on white pine. However, the amount of pine seedlings and saplings now being grown has declined considerably. Forest statistics for New Hampshire between 1973 and 1982 indicate a decline of 24 percent in white pine saplings and 43 percent in white pine pole timber. If there is a decline in white pine saplings, white pine weevil infestations will probably be lower in 1988 and in

1990 or in ten years because weevil injury is only important in young white pine

5. What may have caused or triggered this infestation?
   a. Discuss both primary and secondary factors.

   Weevil injuries may increase on pines growing in an open stand. Injuries can be reduced if young white pines are grown with hardwoods during their susceptible period. White pine stands that have suffered extensive weeviling can be reclaimed. Crop trees have been obtained by selecting codominant and intermediate trees that have escaped serious injury as final crop trees by girdling or removing the badly damaged trees. Environmental and biological conditions are also factors in dictating whether the weevil populations will be high, moderate, or low.

   b. To what extent is aging of the nation's forest related to the incidence of white pine weevil outbreak?

   During the period between inventories, the greatest volume remained in the 12-inch diameter class and this class increased more than any other. Currently, smaller volumes in the 6-inch and 8-inch diameter classes indicate that there are fewer small-diameter trees to form the next crop of sawtimber trees. So, fewer white pine saplings will result in decreased weevil infestations.

6. Describe the possible responses:

   a. Acres treated by type of treatment.

   According to state reports, Maine was the only state to treat white pine to control the weevil. They ground treated about 1000 acres with Metasystox-R and lindane.

   Aerial and ground treatments with chemical insecticides have diminished considerably. Silvicultural techniques are employed now to suppress the weevil populations. No acreage figures are available.

   b. Percent of total infested acres treated. See 6(a)

V. Describe the expected accumulative impacts associated with the white pine weevil.

1. General Impacts

   Loss of the primary terminal shoot causes trees to be crooked and forked. This results in stunted, bushy, crooked trees. Larvae may also kill two and three year old growth. Good grade lumber cannot be obtained from pines that have been weeviled many times. The grain in lumber from weeviled trees is crooked. Weevil injury may be costing Northeastern land owners

and lumber industries as much as $7 million each year due to the most part to lumber degrade that weevil injury causes.

2. Specific Impact

The size of the loss in merchantable volume of standing white pine caused by the white pine weevil was revealed in a study made in New Hampshire in 1955. The average volume loss was 13 percent in pole-size trees (5 to 8.9 inches d.b.h.) or 29.5 million cubic feet, 40 percent in the sawlog portion or over 2 billion board feet of sawtimber trees.

A method for estimating future volume losses using a regression equation was available.

Since trees are not killed by weevil, there is little impact on fire, forage, water, and wildlife. However, crooks and bushy tips caused by weevil injuries lowers the aesthetic value of trees.

VI. Control Response(s)

1. What actions could be taken to control white pine weevil?

A number of techniques and prescriptions have been suggested and developed to control white pine weevil. These techniques fall into three main categories, some of which are listed below:

a. Cultural Control

1. Obtain partial shading of pines with a hardwood overstory to reduce weevil attack.

2. Maintain high density of pines to cause injured trees to straighten more quickly.

3. Take advantage of natural differences in tree condition in reclaiming weeviled pine stands.

b. Biotic Controls

None are currently aavailable for use.

c. Chemical Control

1. Use chemical insecticides to kill adult weevils.

2. Apply granular insecticides to litter to control weevil during hibernation.

3. Apply foliar applications to terminal leaders or upper crowns by aerial or ground applications.

2. What triggers a decision to take action against a forest pest?

Loss in volume due to increase in merchantable height and increased taper and defects within the merchantable length would trigger a decision to take action.

3. What would happen if no action is taken?

Weevil damage in natural stands and plantations present a potential loss to landowners or landmanagers. Volume loss would amount to millions of dollars each year.

4. What can be done to prevent future infestations?

Implementation of silvicultural controls.

VII. Technology Information

1. Describe the adequacy of available technology for prevention or reduction of infestations.

Technologies are available and adequate for reduction of white pine weevil infestations:

1. Plant pines with a hardwood overstory to reduce incidence of weevil population.

2. Maintain high density pine stands to cause injured trees to straighten more quickly.

3. Prune all but one of the laterals in the topmost whorl of live branches to reduce crooks and eliminate forking.

4. Remove and burn newly weeviled leaders.

5. Use registered chemicals to reduce the populations.

6. Use aggregate pheromones complex as a grandisol and grandisal synergistic effect to attract weevils.

7. Manage resistant trees for final crop trees.

8. Destroy over wintering weevils and weevil sites.

2. Describe technology needed to reduce future occurences of weevils?

Integrated pest management (IPM) should be utilized to reduce future losses using one or any combination above.

Promising new chemicals, namely, pydrin, dursban and peremethrin, have been applied in the fall to control adult weevils. Results indicate that they are all very effective on the weevil.

VIII. Treatment Options

1 & 2. Describe treatment techniques, accomplishment and cost.

In Maine, in 1987, about 1000 acres of white pines were ground treated with lindane and Metasystox-R. Efficacy tests indicate that the chemicals were 90-100 percent effective in suppressing the white pine weevil.

3. Cost of Treatment

The cost of the treatment was $25.00/A.

IX. Discuss the observed and expected trends of the next decade for white pine weevil.

No profound changes will likely occur in the observed trends. Landowners are growing fewer pines due to poor markets so less infestation is expected over ten years. Much of the younger pines in managed and unmanaged stands will be beyond the height that is highly susceptible to weevil injuries.

X. In addition to the information required elsewhere in this outline, discuss the following:

1. The obstacles, if any, to the use of existing technology for preventing outbreaks of the pest.

One obstacle is the restrictions that may be placed on chemicals to control the weevil. Another is the lack of work on genetic resistance, especially in jack pine.

2. The limitation placed on effective response to the weevil by laws, policies of the Forest Service, and policies of other Government agencies.

No limitations may be placed on silvicultural practices to reduce white pine weevil injuries, but I foresee that more limitations may be placed on chemicals to control white pine weevil populations. Lindane which has been used for many years to control white pine weevil is now being reviewed by the Special Pesticide Review. If lindane is prohibited for use against the weevil, it will probably set technology back 2-5 years because it is very effective in controlling the adults that feed on the terminal leaders of pines. Landowners may have to rely on Metasystox-R and methoxychlor. Both are effective is controlling the weevil but lindane is very effective, 90-100%.

WHITE TRUNK ROT

I. Other Forest Pest or Forest Decline: White trunk rot caused by *Phellinus tremulae*

II. Ecosystems and geographic "area covered" in this analysis:
Aspen type - Northeastern United States

III. Very brief history and biology of pest or group of pests:

1. Distribution
   a. Description of host vegetation (preferred and secondary)
   Preferred - Quaking aspen (*Populus tremuloides*) and bigtooth aspen (*P. grandidentata*)

   Secondary - Birch, beech, and maple.
   b. What percent of the Northeastern area is occupied by this host type? 11.5%
2. Life cycle
   Spores produced within fruiting bodies (conks) of the fungus are released from early spring to late fall. Sporulation is favored by high relative humidities and warm temperatures. For infection to occur, a spore must fall and germinate on a wound that exposes the wood. The fungus penetrates its host, digesting cell walls causing the wood to become soft and punky. The fungus continues to spread and develop until enough food reserves have been accumulated to produce new fruiting bodies.
3. Cycles and triggers
   This disease is not "cyclic" in nature. Successful infection, however, is triggered by wounding of the host. A tree remains susceptible to attack by this fungus for an indefinite period after the wood has been exposed.
4. How have man-caused changes in natural dynamics of the forest ecosystem influencing fire activity, ecosystem diversity, and nutrient cycling affected the incidence of pest outbreaks?
   Increased fire activity creates tree wounding which in turn leads to a greater incidence of white trunk rot. Other man-caused changes influencing site quality, soil, and nutrient cycling have not been shown to have an influence on this disease.

IV. Summarize the current status of this pest or group of pests.

1. Status of infestations or infection
   This disease contributes more losses due to heart rot than any other disease organism throughout the entire range of aspen.

Heartrot in northern Minnesota is so widespread, that a tree over 20 years of age without infection is rare. in Minnesota 31 percent of the merchantable volume in 80 year-old aspen is affected by white trunk rot.

2. Percent of host type currently infested

In the Lake States where a majority (81%) of aspen resource occurs in the Northeast area, 42% of the merchantable-sized stands are infected with white trunk rot.

3. Acres infested

Approximately 3,300,000 acres of pole and sawtimber size tress are infected with white trunk rot in the Lake States. Using the same infection rate (42%) in the New England and mid-Atlantic states, and additional 1,000,000 acres of merchantable-sized aspen is infected.

4. Probable course of the infestation or infection

a. When could an infestation or infection start?

Tree wounding is required for successful infection of the fungus. therefore, windstorms, logging practices, fire activities, and other injury-inducing events could precipitate infection. Every branch scar is a possible source of infection. Ninety percent of infections are traced to dead, broken branch stubs.

b. Where might it start?

P. tremulae follows aspen throughout its range, and everywhere volume losses are associated with it. Decay increases with stand age and varies by clone.

c. What are the expectations about future distribution and extent?

White trunk rot will continue to occupy aspen's entire range throughout the future. In the Lake States, aspen stands 40 years old and over are subject to breakup due to this disease. Studies indicate that if aspen is grown with adequate protection from fire, and harvested under a shorter rotation, the extent of decay will not be as serious a factor in its future production.

d. Where will it be (area and cycle) in 1988, 1990, ten years?

White trunk rot will maintain its present distribution, and will increase its prevalence in terms of volume loss if we continue to allow our rotation age of aspen to exceed 50 years.

5. What may have caused or triggered this infestation or infection?

a. Discuss both primary and secondary factors. (Specify not only the immediate biological causes but also the chain of events leading up to those causes. Consider management decisions and cultural, economic, climatic and other events.)

The primary factor leading to infection and increasing volume losses of our aspen resource, is the overmaturity and underutilization of stands.

b. To what extent is aging of the nation's forests related to the incidence of this pest outbreak?

A pronounced relationship exists between age and decay. Older stands, as a rule, contain higher proportions of decay than younger stands. The older and larger the tree, the greater is the cumulative risk of wounding and the chance for infection.

6. Describe the possible responses

a. Acres treated by type of treatment

Treatment is impractical in any forest situation.

b. Percent of total infested acres treated

None

V. Describe the expected accumulative impacts associated with this pest or complex of pests.

1. General impacts

Throughout its range, the main factor limiting aspen longevity is stem decay. This disease has determined the pathological rotation age for this species.

2. Specific impacts -- expected changes in yield per acre (vegetation, primarily timber, recreation, wildlife) over the next decade due to damage by this complex of pests)

Timber volume losses due to white trunk rot will vary dramatically according to several factors. The occurrence of decay depends largely on the number, size, and character of tree wounding, while the degree of decay will largely depend on age class of infected trees, and their rate of growth. Wildlife could possibly be enhanced by openings this disease creates in the forest, as deer browse species and other foraging vegetation increases in the understory. High-use recreation areas may have a slight impact from this disease with the unfortunate but necessary removal of hazardous, decaying aspen in campgrounds.

VI. Control Response(s)

1. What actions could be taken to control this infestation or infection?

Direct control of heartrots is next to impossible. However, better utilization can conserve much of the wood now lost as cull, and good management practices will reduce losses from decay.

2. What triggers a decision to take action against a forest pest?

A decision to take action against white trunk rot would be a decision to harvest an aging aspen stand prior to break-up. Therefore, stand age and amount of estimated cull would trigger a decision to take action.

3. What would happen if no action is taken?

If no action is taken, similar volume losses in our future aspen stands can be expected. In addition, as the demand for aspen products increases, increasing volume losses experienced because of "no action" will become more costly.

4. What could be done to prevent future infestations or infections?

Fire is more or less a controllable factor in forest management. Thin-barked aspen is extremely sensitive to fire injury and inevitable infection. Elimination of fires, therefore, would undoubtedly reduce cull. Care should be taken to avoid injuring residual stems. Shorter rotation ages will reduce the incidence and impact of this disease.

VII. Technology Information

1. Describe the adequacy of available technology for prevention or reduction of infestations or infections.

Present technology is adequate. Reduction of volume loss due to decay will take place through proper forest management activities. There is a great need to reduce the large inventory of overmature stands in order to start lowering the average age at which most stands are cut.

2. Describe technology needed to prevent, reduce, or control future occurrences of these infestations or infections.

The possibility that relatively fast growing, decay-free aspen clones is of primary interest. Additional studies should be directed to finding phenological or morphological features associated with resistance. A better system for predicting decay using criteria such as: number of fruiting bodies; tree age; tree size; crown class; stems/acre; and site would be advantageous, and allow forest managers to determine the optimum rotation age for a particular stand. Felling extensively infected trees to prevent spore production is not feasible since the fungus continues to dispense spores for several years after a tree is down.

VIII. Treatment Options

1. Describe treatment techniques, accomplishments and costs

Treatment techniques are restricted to harvesting infected trees/stands before decay becomes excessive. Since *P. tremulae* is a white rot, wood in the incipient and intermediate stages of decay can be used for pulp. Sound forest management practices to minimize losses due to white trunk rot are also sound economic accomplishments, getting a better return on a long-term investment. Costs of harvesting will vary dramatically according to tree size, stems/acre, and area treated.

2. Technique (describe)

Aforementioned

3. Cost of treatment

Aforementioned

IX. Discuss the observed and expected trends of the next decade for this pest or complex of pests.

As long as forest management is limited to relative protection from fire, slow harvesting of existing stands, and unmaintained creation of wild, second growth aspen stands, similar losses can be expected during the next decade.

X. In addition to the information required elsewhere in this outline, discuss the following:

1. The obstacles, if any, to the use of existing technology for preventing outbreaks of the pest.

Obstacles for reducing the impact of this disease would include resistance from the public in harvesting decaying aspen stands, which appear otherwise healthy from the outside.

2. The limitations placed on effective response to the pest by laws, policies of the Forest Service, and policies of other government (federal, state, local) agencies.

None

XI. Recommendations

a. Further analysis needed.
Methods to predict decay

b. Added information needed.
None

c. Actions needed now.
Harvesting over-mature stands

d. Actions needed within 5 years.
Maintain aspen rotation to 40-50 years

WHITE PINE BLISTER RUST

II. Ecosystem and geographic "area covered " in this analysis.

This analysis is restricted to the eastern white pine forest type and the Northeastern Area.

III. History and biology of white pine blister rust.

1. Distribution

a. Description of host vegetation.

Eastern white pine (Pinus strobus) has a wide distribution. In the Northeastern Area, natural stands occur in every state except Missouri. It is usually found on well drained soils that are favorable for growth of pine, but not of aggressive hardwoods. White pine can also establish itself on less well drained sites where there is no hardwood competition during the establishment period. As a result of the disturbances created by and after the settlement of the East, white pine is now often found in nearly pure stands.

b. Proportion of the Northeastern Area occupied by the host type.

In the Northeastern Area, the eastern white pine forest type occupies 4,191,000 acres in the 15 states with significant acreages or about 3 percent of the forested area of those states. The species is also an important component of several other forest types. Within the Northeastern Area, the states of Maine, New Hampshire, Vermont, and New York contain two thirds of the eastern white pine forest type.

2. Life cycle of the pathogen.

The white pine blister rust fungus, Cronartium ribicola Fisch., is a long cycle, heterecious rust. It produces five types of spores and requires an alternate host - species of Ribes (gooseberries and currants) - to complete its
life cycle.

Pycnia first form in the bark on cankers during August of the third season after infection. The following spring, aeciospores are produced in the same area where the pycnia were formed earlier. Aeciospores are thick-walled and resistant to adverse environmental conditions. Thus they can spread for hundreds of miles from pines to reach susceptible Ribes spp.

About two weeks after successful infection of Ribes leaves by aeciospores another spore stage called urediniospores are produced in small, orange pustules. The urediniospores carry the fungus from Ribes leaf to Ribes leaf on the same or nearby plants, intensifying and spreading the disease throughout the summer.

In late summer or early fall, telia appear on the underside of the Ribes leaves. The telia produce teliospores, which germinate in place to form yet another spore stage called basidia. The thin-walled basidia can infect the needles of pines no further than a mile from the Ribes plant. The fungus soon

grows from the needle into the stem and, about three years after infection, pycnia form to begin the cycle again.

3. Cycles and triggers

Production of basidia by the blister rust pathogen and subsequent spread to and infection of pine requires a continuous period of at least 48 hours of temperatures below 20°C and free moisture on the needle surface. Thus the most severe damage to the white pine resource occurs where and when cool, moist conditions prevail. This is in the more northerly parts of the range of white pine, at the higher elevations, and during certain "wave years" in which the fall is wetter and cooler than usual.

4. Effect of man-caused changes.

Early settlers of the eastern United States cleared most of the forests away for farms. New Hampshire, for example, was only 48 percent forested in 1870. After 1870, most of the farmland was abandoned, a gradual process that continued until about 1960, at which time the state was 87 percent forested. The pattern was similar, if less pronounced, for other eastern states. In the Lake States, after settlement the proportion of land area in the white pine type declined as a result of lumbering and subsequent fires. In Michigan, more than 100 billion board feet of white pine were cut between 1849 and 1909. Today the total inventory is 2.6 billion board feet.

White pine blister rust was introduced to the eastern seaboard at Kittery Point, Maine, near the New Hampshire border, about 1897. In 1897 New Hampshire was about 58 percent forested, thus about 600,000 acres of farmland had reverted to forest in the ensuing 27 years and another 1,700,000 acres would revert in the next 63 years. White pine establishes itself readily on abandoned farmland, so we can assume a large portion of this land was in young white pine, or soon would be, when the disease was introduced. The rust is most damaging to young stands, so an ideal situation for catastrophic losses had been created by the clearing and subsequent abandoning of the land. The abandonment of farmland continues, but at a far slower pace, and the effect on the white pine resource has been dramatic. In New Hampshire the portion of the white pine forest type in seedlings and saplings declined from 22 percent in 1973 to 9 percent in 1983. As there are fewer young stands we can expect less damage from the disease.

IV. The current status of white pine blister rust.

1. Status of the infestation.

White pine blister rust is present in most, if not all, of the states with significant acreages of eastern white pine, but is of consequence only in the Lake States, northern New England, New York, and to lesser degree West Virginia. White pine stands in the Northeastern Area were surveyed for infection in 1971. The data for Lake States stands indicated an infection rate for the years 1961-64 of 1.1 percent per year (in four eastern states it was about 0.5 percent per year). The overall average infection rate, then, is probably around 1 percent per year, though in individual stands the rate can reach 5 percent or even more.

2. Area and percent of the host type infested.

While all of the type is infested, only a portion is vulnerable to damage. About 80 percent, or 2,670,000 acres, of the white pine forest type in New York, New England, and the Lake States are in the medium to high hazard zones. Forest statistics for the eastern states indicate about 10 percent, or 267,000 acres, in seedling and sapling stands.

3. Probable course of the infestation.

a. When an infection period could start.
As explained in III. 3. above, infections occur only when and where the weather conditions are moist and cool in the fall. A period of moist, cool falls could start at any time, but there is no reason to expect such a period.
b. Where might an infection period start.
In the eastern part of the Northeastern Area, white pine is still invading abandoned farmland. However, most of this land is in the southern portions of the white pine range where the blister rust hazard is low. In the midwest, the present farm crises may result in substantial increases in abandoned farmland, but the proportion that might revert to white pine would probably be minor. Thus, no significant increase in infection is likely unless foresters undertake a great effort to harvest and regenerate white pine stands, or convert other stands to white pine, in the more northern portions of white pine range.
c. What are the expectations of future distribution and extent.
White pine blister rust has already spread to essentially all of the white pine range. Within the range, the proportion of land in the white pine type is
declining or has stablized, declining in the northern portions and increasing in the southern. As the northern stands mature, and are not replaced with young ones, the incidence of blister rust will decline.
d. Where will the cycle and what will the area be in 1988, 1990, ten years.
No significant change should be expected by 1990. By 1997, the area in vulnerable age class should have shrunk by at least another 10 percent - to about 240,000 acres.

5. The cause or trigger of the infestation.
a. The activity of the fungus is controlled by local climatic conditions.

b. As the stands of eastern white pine age, many are not being cut. New Hampshire is the only state in the New York - New England region, where the cut equals growth. In the region as a whole growth is about 1.8 times the cut. As a result, the proportion of the resource in smaller trees is declining. Moreover, the reversion of farmland to white pine is in the southern, less hazardous areas. Both these factors add up to a lower incidence of blister rust.

6. Possible responses.

a. From the 1920s to the 1970s the battle against blister rust was conducted on a large, sometimes massive scale. By 1961, some 6.5 million acres of white pine in the Northeastern Area (excluding West Virginia and Maryland) had been treated by destroying the alternate host plants, Ribes spp. Estimates for treatment by excising the lower branches of white pines are not readily

available, but an office report for 1966 indicates 3900 acres were treated in that year. The method had not been used extensively until 1963 (Brown 1972), and little work of any kind was done after 1972, so we can conclude that less than 50,000 acres were treated by excising branches.
b. The total acreage treated, as recorded above, exceeds the current total

acreage of the white pine type. The discrepency is probably due to duplication
- many areas were treated more than once. Whatever the case, the portion of the resource that merited treatment, and was treated, is close to 100 percent. At the present time only the states of Maine and West Virginia have blister rust control programs.

V. The expected accumulative impacts of white pine blister rust.

1. General impacts.
C. ribicola infects a pine through the needles. If the point of infection is within 18 inches of the stem, the infection is considered lethal to the tree. Most infections occur close to the ground where the coolest, dampest air is found. Larger trees do not have many of their needles within 18 inches of the stem close to the ground therfore most mortality occurs in younger stands. A notable exception occurs along the northern shore of Lake Superior in Minnesota, where large trees are killed due to unusual climatic conditions. In the younger stands, tree mortality can reach 60 percent or more.

2. Specific impacts.
While the losses in indiviual stands can be extremely high, the overall

rate of lethal infections is about 1 percent of the trees per year (see IV 1. above). If we assume the average pine will grow from seedling to pole size in 20 years, about 20 percent of trees will die as a result of the infections. If we further assume that all of these trees are needed to realize a fully stocked stand of mature white pine, the losses would be about 53,400 acres (20 percent of the 267,000 acres in seedling and sapling sized stands) in the next 20 years, or 2670 acres per year. If we use the figure of $169 per acre as the present value, the loss in timber value is $451,000 per year, or $4,510,000 in the next decade.

Though it is difficult to quantify, white pine has great scenic value. It also has value as one of the softwoods that form wintering areas for deer. The impact of white pine blister rust on these values is not known and would be difficult to determine.

VI. Control responses.

1. On an Area-wide basis, blister rust already seems "under control". The infection rate is only 1 percent per year and the disease is dangerous primarily to trees 20 years old or younger. On a local basis, stands can be destroyed by the disease, and either the destruction of nearby Ribes or the excision of lower branches may prevent this.

2. Until 1972, the mere presence of Ribes in or close to a stand was enough to trigger treatment. Since then, on the few Federal cooperative projects undertaken, only those stands with infection were treated. The state of Maine

personnel "scout" white pine areas, destroying the occasional Ribes found, and leaving heavy concentrations to the towns and landowners. About 300 acres per year are treated by the towns and landowners.

3. The 1971 survey of young white pine stands in the Northeastern Area (see IV 1. above) showed no difference in infection rates before and after treatment (destruction of Ribes). Previous studies had shown great benefit from such treatment. Similar contradictions appear in the literature on branch excision. Thus we are not certain that anything of significance would happen if no action is taken.

4. Where white pine is planted, the use of resistant seedlings would reduce infections. Some resistance to the disease has been found in a few eastern white pines, but as yet it is not high enough in the offspring to warrant widespread planting. Resistant hybrids, such as *P. strobus* X *P. wallichiana*, have been developed but are not widely available.

VII. Technology information.

1. The contradictions in studies of control efficacy indicate that we do not adequately understand the conditions affecting infection. Thus control efforts are entirely on a "hit or miss" basis.

2. A computerized model incorporating all the topographic, meteorological, and biological factors that would affect infection in a particular stand is needed. This would allow us to focus our efforts where they are most likely to succeed.

VIII. Treatment options.

1. The usual technique for controlling white pine blister rust, which was used in Europe even before blister rust reached North America is the destruction of the alternate host plants close to (typically within 900 feet) white pine stands. Ribes were rogued manually until herbicides became available in the 1950s. Ribes eradication costs about $11-$18 per acre of pine protected. About 100,000 acres or 2.6% of the pine type could be treated for Ribes eradication.

2. The excision of the lower branches of the host tree, or "pathological

pruning", was developed as a technique after it was found that about 90 percent of the infections occurred within six feet of the ground. Pruining guidelines called for 200-350 trees per acre to be completely pruned for one-half their heights or nine feet, whichever is less. The cost of this method of control would be about $57-91 per acre.

3. The observed and expected trends of the next decade for white pine blister rust.

For the reasons explained above (III. 4, IV. 3a) the portion of the white pine resource in the vulnerable age class, and in the areas of high hazard, is declining, and there is no reason to believe that this trend will change in the
next decade. Therefore the incidence of disease will decline.

X. Other information.

1. Other than the question of efficacy of the treatment methods, the only obstacle to the use of existing technology to prevent outbreaks of white pine blister rust is public aversion to the use of herbicides. The Federal cooperative blister rust program was (de facto) phased out before the use of herbicides in the forest became controversial. However, if another large scale program were undertaken, the problem would no doubt arise.

2. The laws and governmental policies concerned with the use of pesticides would place limitations on the use of herbicides to destroy Ribes. This is particularly true of the NFS policies. However, only a small portion of the eastern white pine resource is on the National Forests, and most states allow the use of herbicides. In short, the limitations are not a serious barrier to control.

XI. Recommendations

a. No further analysis is needed.
b. The compilation of, and perhaps expansion of, information on the meteorological aspects of the disease is needed.
c. and d. The only action needed now, or in the next five years, is the creation of the computer model mentioned in VII. 2. above.
*

OTHER PESTS IN THE SOUTH

Dale A. Starkey

Includes:

-Hardwood decline
-Annosus root rot
-Littleleaf disease
-Sand pine root disease

HARDWOOD (OAK) DECLINE IN SOUTHERN FORESTS

IDENTITY

The term "hardwood decline" refers to a disease syndrome which results in dieback and mortality of hardwood trees (primarily oaks). This disease, variously called "hardwood decline", "hardwood decline/mortality", "oak decline", or "oak decline/mortality" is a complex one in which a variety of pests and other factors contribute to the overall expression of the disease. The fact that oak species are of primary interest to timber, wildlife and recreation interests concentrates concern on these species, even though others may be affected. The disparity between the importance of oaks and other species is great enough that the term "oak decline" is more often used and is probably the most accurate term applicable in the south.

ECOSYSTEMS AND GEOGRAPHIC AREA

Oak decline affects the southern region of the United States as defined by the 13 state area designated as the Southern Region or Region 8. Region 8 contains 3 physiographic regions: the mountains, piedmont and coastal plains.

HISTORY AND BIOLOGY

Distribution and Description of Host Vegetation

Host forest types affected by hardwood decline in the south include all oak, oak-hickory, mixed hardwood and bottomland hardwood forest types with the exception of swamp forest types such as cypress-tupelo or other wet site types such as beech-magnolia. These types comprise approximately 102 million acres in the Southern Region (as of 1985) and are broken out by forest type in table 1. This amounts to 53% of all southern timberland acres (although this figure includes the swamp forest types mentioned above).

Disease Biology

Hardwood decline is a complex disease caused by a variety of factors, acting in combination. Among these factors are defoliating insects, drought, frost, root disease fungi, canker fungi, boring insects and soil and site factors. While a number of these factors have been reported to cause decline singly, the majority of reports indicate that two or more factors are usually responsible. In general, a factor(s) puts host trees under abnormal stress making them more susceptible to insect and disease organisms which operate more aggressively on compromised hosts (Wargo et al. 1983).

The resulting physiological effects on host trees initiate a pattern of dieback, generally inward from the branch tips, from the top of the crown down and the outside of the crown in. Other symptoms accompanying dieback may include chlorotic, dwarfed foliage, sparse foliage, development of epicormic sprouts on the main stem and large branches, premature autumn coloration, premature leaf fall, leaf scorch or wilt and foliage death in a portion or all of the crown. Reduced growth of branch tips may produce a tufting of remaining foliage. Some trees die suddenly with little decline. Most exhibit decline symptoms for a number of years before dying (Wargo et al. 1983).

Decline begins when abnormal stress is put on trees by defoliating insects, drought or frost. Defoliators commonly associated with decline are the gypsy moth *Lymantria dispar* L., and spring defoliators (linden looper, *Erannis tiliaria* (Harris); spring cankerworm, *Paleacrita vernata* (Peck); fall cankerworm, *Alsophila pometaria* (Harris) and eastern oak looper, *Phigalia titea* (Cramer)). These factors place trees under stress by disrupting normal physiological functions, depleting food reserves and decreasing growth (Wargo 1981). Trees thus weakened are much more susceptible to attack by other insects and diseases.

Those most often associated with decline are *Armillariella mellea* (Vahl. ex Fr.) Karst., (armillaria or shoestring root rot) and the 2-lined chestnut borer *Agrilus bilineatus* (Weber) (Wargo 1977). *A. mellea* exists primarily as a saprophyte on stumps and roots but is able to invade weakened roots and upon spreading to the root collar is capable of killing large portions of the basal circumference. The 2-lined chestnut borer also appears to aggressively attack weakened trees. This insect bores into the inner bark of trees and creates meandering galleries. As the larvae grow and the number of galleries increase, large areas of the stem are girdled.

Other factors related to decline are a ridge topographic position, shallow or rocky soils and a low site index (Starkey et al. 1987). Other contributing factors might be stand age (maturity-overmaturity; McGee 1984) and poor genetic composition (result of past cutting practices; McGee 1982). There is also strong evidence to suggest that trees which exhibit decline or mortality have had significantly lower growth rates for up to 20 years prior to decline (than trees of the same species, size and position; Starkey et al. 1987, Tainter et al. 1984).

Cycles and Triggers

Oak decline appears irregularly in relation to either climatic trends (such as drought) or to severe levels of defoliation by insects (which tend to appear in cycles). In either case the drought or defoliation (severe or repeated) acts as a trigger to initiate a period of hardwood decline. Episodes have not been adequately monitored in order to determine their longevity or the related factors, however, there appears to be a general lag time from stress of 2-5 years in affected areas. The effects of decline may linger for many more years. Total tree mortality often occurs in the year of acute drought stress or the following year (Mistretta et al. 1982) while mortality following severe insect defoliation seems highest 2 years later (Wargo et al. 1983). Decline occurs concurrently with mortality and may last several years.

CURRENT STATUS

Oak decline is currently widespread over the Southern Region but is irregularly distributed and varies widely in severity. Hardwood decline probably exists at a very low level on a majority of the acres of host type in a given year. Severe occurrences, however, are associated with more limited geographical areas. No data exist on the number of acres affected. Virtually every southern state has reported areas of decline since 1980 (Starkey 1985). Some states report much greater problems and more affected area due to the amount of suitable host type and physiographic factors. The mountain areas of Virginia, North Carolina, Tennessee and Arkansas have been particularly affected. In addition, west-central Tennessee has sustained high level of decline in some areas. Results from the ongoing R8 Hardwood Decline Survey (available FY88) will provide estimates of the extent and severity on three R-8 Ranger Districts.

Outbreaks of hardwood decline could, conceivably, begin at any time when triggered by episodes of defoliation, drought or other widespread stress factor. These factors tend to run in cycles although not necessarily predictably. Outbreaks can occur almost anywhere within the host type, however, since site factors are known to be somewhat related to the occurrence of decline, areas which have a history of decline or which have certain site characteristics will probably experience decline again. It would appear that a rudimentary hazard rating scheme might be devised to predict where, or under what stand and site conditions, decline would be most likely to develop (in the event of a widespread predispositional factor). Data collected by R8-FPM in 1985 and 1986 will provide a simple hazard rating scheme useful to forest managers in understanding and anticipating decline (figure 1).

Future episodes of decline are certain. Recorded decline events have been known since the 1920's in nearly every eastern state with hardwood host type (Tainter 1985). There is every reason to expect that episodes of decline will occur again. Areas with characteristics identified in figure 1 will have decline episodes in the future, although the exact location, extent and severity cannot be predicted.

IMPACTS

Decline results in trees with reduced growth rates or tree mortality which may occur immediately or after several years. Yields are necessarily reduced unless prompt salvage can be undertaken. In addition, opportunities for control of stand composition are diminished because tree species are differentially damaged and rootstocks (needed for coppice reproduction) are weakened or killed. Besides timber values, recreation and wildlife values will also be impaired. Oaks are the primary mast-producing species of interest and are of recreational value since they are long-lived, sturdy, aesthetically desirable and associated with high wildlife production.

The impact of decline has been described in numerous reports which cannot be summarized here. Impacts measured by R8-FPM on 38 stands in 9 states (in 1985-86) can provide an example (Starkey et al. 1988). For all dominant and codominant trees, an average 17% (per acre) were dead and 20% had advanced decline. Among oaks, 24% of red (black, scarlet) oaks were dead and 24% in advanced decline while white oaks (white, chestnut etc.) sustained only 18% mortality and 19% advanced decline. Hickory had 12% mortality and 17% advanced decline while other species had 4% mortality and 10% advanced decline. Thus, species composition is expected to change as a result of oak decline.

Few studies have been conducted to measure volume losses due to decline. Estimated losses due to current mortality (over past 5 years), projected mortality (for next three years) and projected growth loss (over the next 10 years) are being calculated for the stands mentioned above.

CONTROL and MANAGEMENT RESPONSE(S)

No direct control methods are currently available for oak decline. Drought and frost are recurring phenomena over which we have no control. Epidemics of defoliating insects (primarily gypsy moth; Doane and McManus 1981) can and have been controlled by chemical means but control is temporary, expensive, difficult to coordinate and generally limited in scope. No effective, feasible control methods are available for pests such as *A. mellea* and *A. bilineatus*.

Mitigating measures (used to reduce losses from oak decline) could be applied. Salvage of dead and declining trees from affected stands would capture mortality and, perhaps, provide some additional growing space, moisture and nutrients to residual trees. While this response appears feasible, it's application is hampered by low resource values and volumes per acre. It is probably infrequently applied. Salvage initiated in a stand when decline is light or moderate could be coupled with additional thinning and might provide some reduction in decline severity for the next few years.

Regeneration of severely affected stands is probably a better option. Prompt regeneration would capture affected volume and also provide for more control over species composition since a greater diversity of live rootstock would be available for sprouting. Older trees, approaching or past harvest age are less elastic in their response to environmental stress

and much more susceptible to decline. As decline becomes evident, harvest of these stands would return them to a younger, productive, and, perhaps, more diverse species composition.

There is evidence to suggest that oak-hickory forests allowed to age and decline begin to lose the predominance of oaks over other species and are replaced in the overstory by species such as sugar maple, white ash, yellow-poplar, etc. (McGee 1986). Oak decline would likely hasten this result.

Sound preventive techniques are also lacking for oak decline. Periodic thinning of healthy stands might help retain vigor of oaks into older age categories (Sonderman 1984, Sonderman and Dale 1984, Graney 1983), although stem quality can be reduced unless careful stocking control is maintained.

Several management options should be considered in seeking long-term relief from the effects of oak decline. While definitive data associating older trees with decline and mortality are generally lacking, it is evident that most affected stands are in the 70-100+ year old class (Starkey et al. 1988). If such stands were harvested at an earlier age, especially in areas likely to sustain decline, losses might be significantly reduced. Oak decline should probably be a strongly considered factor when setting rotation ages for upland oaks. Rotation ages should probably vary by site productivity or by risk to decline.

Species conversion (primarily to pines) on the drier, poorer sites now occupied by hardwoods would boost timber production. A single rotation of pine, followed by a rotation of pine-hardwood then followed by a rotation of hardwood would increase volume production over several rotations but would allow hardwoods to be a significant proportion of the stand for 2 of 3 rotations. If judiciously applied to the appropriate sites this should be a viable option. Less intensive pine management on these sites might be used to create pine-hardwood stands where the most appropriate hardwood species as well as pine could be favored in intermediate silvicultural treatments.

A third option for dealing with oak decline would be to assign low quality, dry oak sites with little potential for significant timber production to a management category for non-timber resources (such as recreation, wildlife and watershed) and effectively cease management. It must be understood, however, that minimal management may result in undesirable shifts in species composition away from oaks (McGee 1984).

TRENDS

No data exist to suggest regular or future trends in the occurrence or severity of oak decline. It has probably been present since before recorded history and certainly since (Tainter 1985). However, it appears that, in general, as hardwood forests age and rotation ages are increased, the occurrence and severity of decline can only increase too.

OBSTACLES AND LIMITATIONS

Obstacles or limitations to effective response to oak decline are: (1) low resource value (commodity value), and (2) regulations and policies which limit management options. Oak timber has the unique quality of being rather low in commodity resource value (on the stump) yet in high demand for its value as a forest component by recreationists, hunters and wildlife enthusiasts. This low commodity value severely hampers management options since anything less than harvesting an entire stand (or at least all the best timber in it) results in revenues too low to justify the operation. Therefore, intermediate stand treatments for any purpose are rarely feasible on the average oak site and a need exists for expanded markets, new products and utilization techniques (McGee 1982).

Regulation and policy limitations are primarily that of a specified rotation age for all upland oak sites and the restrictions against converting even low-quality hardwood stands to more productive pine species. Most of these restrictions have been implemented in the Forest Planning process recently accomplished on most R8 Forests.

QUESTIONS

a. Age of the nation's forest is probably related to the extent and severity of decline as discussed above.

b. Forest Plans address forest pests in a competent manner in most cases but detailed treatment cannot be included. Unfortunately, for problems such as oak decline, policy restrictions limit management response more than any lack of awareness of the problem. This is well after substantial growth or volume loss has already occurred.

c. Actions are triggered against any pest, including oak decline generally when the problem or its impact becomes highly visible or a nuisance. With oak decline, only many trees declining or dying in a given area seems to generate management interest.

d. As might be expected, the public's knowledge of forest ecology and management is insufficient to understand the many and varied relationships affecting forest health. For instance, the public views oak trees as being long-lived, therefore, rotation ages should 100-200 years, irregardless of site quality, species composition, successional trends, age-class distribution of the forest etc.

e. Regarding oak decline, the technology for enhancing or maintaining forest health exists, at least in part. Identifying decline-prone sites can be accomplished to a limited extent, and other silvicultural technologies could be applied to stands to increase their vigor and productivity (McGee 1982).

f. Man-caused changes relating to oak decline are primarily a result of past cutting practices. Past selective cutting of the highest quality trees has left the poorer quality (form and genetic) trees to grow into the stands we have today (McGee 1982).

g. Public involvement has primarily resulted in increased pressure for longer rotations for hardwoods and the cessation of conversion of low value hardwoods on poor sites to pine management.

h. Public perception of oak decline at the current time is that it is caused by acid rain. They do not relate to the known factors involved, nor understand the flexibility needed to deal with the problem.

i. Land ownership class does not appear to have much affect on the frequency or intensity of oak decline. However, the National Forests, in general, tend to have some of the poorer quality timberland and therefore, a good portion of the oak decline.

RECOMMENDATIONS

Further analysis of the oak decline problem needs to be directed at specific aspects of the problem which need clarification. Some potential areas include:

1. Since regeneration of oak stands is generally a problem; (a) what are the ultimate effects of oak decline on the success of regenerating oak, and (b) at what level of decline is the success of oak regeneration affected?

2. What benefits can be obtained by thinning hardwood stands to maintain greater vigor? Do such treatments actually prevent or lessen the severity of subsequent outbreaks of oak decline?

3. What, if any, is the relationship of oak decline to air pollution or acid rain?

4. What are the non-timber values of hardwood stands which might justify stand treatments to maintain high components of oak for wildlife and recreation interests?

Some changes which would improve the National Forest land managers ability to deal with oak decline might be:

1. Greater flexibility in rotation ages -- perhaps set according to species composition and site productivity.

2. Ability to convert some low quality, low site index hardwood areas to pine for at least one rotation to provide for greater volume production -- this (contrary to general public opinion) would also benefit wildlife by creating greater diversity on a given forest.

Figure 1. Hazard-rating scheme for oak decline and mortality.

Low Damage Potential	High Damage Potential
Younger stand (< site index?)	Old stand (> site index?)
Composition predominantly white oak group	Composition predominantly red oak group
Mesic site conditions	Xeric site conditions
Loamy soils, few rocks	Rocky soils
Deeper (> 18") soils	Shallow (< 18") soils
Coves, terraces, bottoms, lower slopes	Ridge or upper slope
North and east aspects	South and west aspects
High site index ($\leq$70)	Low site index (>70)
Little past decline history	Past decline history
Little past defoliation history	Past defoliation history

Table 1. Hardwood acres (thousands) in southern states.[1/]

	Upland Hardwood	% of All Hdwd	Bottomland Hardwood	% of All Hdwd	All Hardwood	% of All Forest	All Forest
Alabama	7,482	75	2,430	25	9,912	46	21,577
Arkansas	5,970	69	2,687	31	8,657	54	15,950
Florida	1,988	31	4,358	69	6,346	41	15,337
Georgia	5,976	63	3,575	37	9,551	41	23,535
Kentucky	7,590	77	2,290	23	9,880	83	11,902
Louisiana	2,213	32	4,735	68	6,948	50	13,797
Mississippi	4,347	55	3,490	45	7,837	49	16,072
No.Carolina	7,059	72	2,703	28	9,762	53	18,358
Oklahoma	2,210	85	395	15	2,605	61	4,270
So.Carolina	3,001	57	2,266	43	5,267	43	12,133
Tennessee	9,481	92	819	08	10,300	80	12,937
Texas	3,001	60	2,012	40	5,013	41	12,118
Virginia	9,773	94	618	06	10,391	67	15,436
TOTAL	70,091	68	32,378	32	102,469	53	193,422

1/ **From:** The South's Fourth Forest: Alternatives for the Future. Review Draft. Washington, DC: U.S. Department of Agriculture, Forest Service; 1987. 611 p.

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ROOT DISEASES

Includes:

Annosus root rot
littleleaf disease
sand pine root disease

IDENTITY

This report will cover three main root disease problems in southern pines - annosus root rot, littleleaf disease (loblolly pine decline) and sand pine root disease.

ECOSYSTEMS AND GEOGRAPHIC AREA

For annosus root rot the entire range of southern pines is considered and the ecosystems include coastal plain, piedmont and mountain areas. The area under consideration for littleleaf disease is much more limited and includes an area within the piedmont physiographic region stretching from central Virginia in an arc through middle Alabama. This area is within both the biological and commercial range of shortleaf pine. Sand pine root disease is geographically restricted to the natural range of sand pine in Florida (also Baldwin Co., Alabama) and sandhill sites in Georgia, South Carolina and Alabama on which it has been introduced in plantations.

HISTORY AND BIOLOGY

All southern pine species are susceptible to annosus root rot caused by the fungus Heterobasidion annosum (Fr.) Bref. (= Fomes annosus (Fr.) Karst.) although susceptibility varies and some (e.g. slash, loblolly, eastern white) seem more damaged than others (e.g. longleaf). Therefore, this disease has an extremely wide geographic and host range. However, annosus root rot causes significant damage primarily in pine plantations (or natural stands pure enough to have the general characteristics of plantations). Considering pine plantations as the host type for which the greatest threat exists approximately 21,622,000 acres in the south are potential host type (table 1).

Annosus root rot is a disease of thinned stands (Robbins 1984), particularly pine plantations. The fungus enters the stand as spores through fresh cut stump surfaces, colonizes the stump and roots and spreads to remaining healthy trees by root contacts or grafts. Damage is expressed by reduced radial growth rate, crown symptoms such as sparse, tufted, off-color foliage and tree death. Mortality seems to peak about 3-5 years after a stand becomes infected. Mortality becomes less frequent thereafter and by 10 years post-thinning is fairly uncommon. Trees often show symptoms and die in pockets or infection centers which slowly increase in size. Conks of the fungus are produced at the base of stumps, dead or infected trees, usually below the litter layer. These release airborne

spores which are available to reinfect other cut stumps in the vicinity. Annosus root rot is most severe on deep, well-drained sandy soils with no clay layer or high seasonal water table within 12" of the surface.

Littleleaf disease primarily affects shortleaf pine but may also affect loblolly pine. However, loblolly is somewhat less susceptible and the disease on this host is sometimes termed loblolly pine decline. An estimated 4,185,700 acres of shortleaf pine host type are present within the range of this disease (table 2).

Littleleaf disease is caused by a complex of factors (Mistretta 1984) including the soil fungi Phytophthora cinnamomi Rands. and Pythium spp.; poor site factors (i.e. eroded heavy clay soils with poor internal drainage and deficient in nitrogen) and nematodes. Shortleaf pine above the age of 20 on the described sites are most severely affected. Crown symptoms such as dwarfed, chlorotic foliage, reduced terminal, lateral and radial growth, distress cone crops and dieback. Trees may die in 6-12 years.

Sand pine root disease has a very limited host range in that it is known only to sand pine. The range of sand pine itself is very limited (i.e. 537,300 acres in Florida, 15,300 acres in Georgia, and additional planted acres in South Carolina and Alabama; table 4). Sand pine is most common and grows best on sandhill type soils. About 2,001,510 acres of these soil exist in Florida (Barnard et al., 1985). Additional areas of sand hills occur in a narrow band through central Georgia, South Carolina and into North Carolina. Planting has been extended into these areas in an effort to obtain higher volume yields from these dry, poor soils (Hebb 1982).

Sand pine root disease is a complex disease possibly involving as many as eight known or suspected fungal root pathogens (Barnard et al. 1985). Two appear to be of greater importance: Inonotus circinatus (Fr.) Gilbertson (= Polyporus tomentosus Fr. var. circinatus Sartory & Maire) in mature and overmature trees, and Phytophthora cinnamomi in young, planted trees. Other fungi which may at times play a role are Armillaria tabescens (Scop. ex Fr.) Singer (= Clitocybe tabescens Bres.), Verticicladiella procera Kendrick, Macrophomina phaseolina (Tassi) Goid., Phaeolus schweinitzii (Fr.) Pat., Heterobasidion annosum and Phytophthora parasitica Datur. However, little is known about the exact role of these latter fungi. Affected trees exhibit a variety of symptoms such as crown thinning, foliar discoloration, basal cankers, basal resinous, windthrow or leaning (Barnard 1979, 1980, Ross 1970). Little is known about the complex etiology of this disease. However, the apparent association of P. cinnamomi with planted stands, its occurrence in forest nurseries and the fact that it is an introduced pathogen in the U.S. suggest it may be introduced to planting sites via infected nursery stock or contaminated forestry equipment (Barnard et al. 1985).

None of these diseases are triggered by any particular phenomenon, nor are they cyclical in the sense that they increase and decrease in a regular manner. Rather, these diseases are always present at some level. Levels of incidence may fluctuate due to various factors but these are, at present, beyond reliable detection.

CURRENT STATUS

Annosus root rot is currently widespread on pine plantations in the southern region, however, no estimates of the number of infected acres on a regional basis are available. It is probably more common in loblolly and slash

plantations due strictly to their abundance. There is evidence to suggest that annosus is also probably widespread and common in natural stands, although serious damage is usually lacking (Starkey and Richins 1985).

Littleleaf disease is widespread throughout its range and an estimated 1,395,100 acres of forest are currently affected (Mistretta 1982). This represents approximately 23% of the available host type.

Sand pine root disease is widely distributed in Florida within the natural range of sand pine and is also known to occur in Georgia and South Carolina. Recent estimates of infected acres are 456,800 for Florida (85% of host type) and 11,000 in Georgia (72% of host type). Acreage of sand pine in South Carolina and Alabama are very small and no estimates exist.

IMPACTS

Quantification of root disease impacts are difficult. Confirmation of infection is perhaps the greatest obstacle since it is time consuming, labor intensive and impractical over large areas. However, attempts at quantifying impacts have been made in specific instances and provide examples of resource loss. All three root disease problems considered here impact pine stands by causing mortality and growth reductions, principally by impairment of root functions.

Many attempts have been made to quantify losses due to annosus root rot. A southwide survey of thinned stands in 1962 estimated 2.8% of planted loblolly trees were dead, 2.2% of planted slash. Fifty-nine percent of planted loblolly stands were infected while 44% of planted slash were infected (Powers and Verral 1962). A survey in Tennessee estimated an average 2% mortality at about 7 1/2 years post thinning and a volume loss of 1/10 cord per acre per year since thinning (Appelgate 1971). A Virginia survey estimated a volume loss due to mortality of 1/2 cord per acre per year 5 years after thinning or 6.7% of total volume (Morris 1970). Losses of 1.2-1.8 cords per acre per year were estimated at 5 years after thinning of slash pine in Georgia (Driver 1961) and a statewide survey in Alabama estimated a current value loss of .4 cord and 81 bd. ft. per acre (Kucera and Ryan 1986).

Growth losses due to annosus root rot have also been estimated. In infected Georgia slash pine reductions in radial growth of 20-32% were measured 4-6 years after thinning (Froelich et al. 1977). A Virginia study estimated a 4% annual and 19% 5-year loss in radial growth of infected loblolly pine (Bradford et al. 1978). Such weakened trees are also suspected of being attractive sites for SPB attack (Alexander et al. 1981).

Compared to annosus root rot the impact of littleleaf disease has been little studied. A study based on 1947 Forest Survey data for South

Carolina estimated that in 9 counties with abundant littleleaf 4.2% of shortleaf pines were affected. These represented 6.4% of the cubic-foot volume and 7.8% of the board-foot volume. Growth loss of loblolly pine on littleleaf disease sites in South Carolina has been recently studied (Oak and Tainter 1987).

Since sand pine root disease was only recently discovered, specific losses have received little study. A 1980 survey of 200 Florida stands estimated average disease incidence at 4.5% of trees but ranged as high as 42% in one stand (Barnard et al. 1982). Statewide economic impact was estimated at $1.5-2.5 million annually. Losses on the Ocala NF in Florida were quantified in 1980 (Oak et al. 1981); estimated cubic-foot volume losses ranged from 0 to 26 feet per acre, an estimated $500,000 loss for 1980. Estimated mortality losses in Florida and Georgia amount to some 12.5 million trees and over 4 million cubic feet of timber (Oak 1983).

Impacts of these diseases on wildlife and recreation have not been studied but are probably minimal except for annosus root rot in recreation areas. Wildlife may benefit from openings created by dead and dying trees due to increased forage production. This would be especially true for deer and turkey. Recreational hunting might be improved. Annosus root rot has an impact on recreation in managed forest recreation sites. Often-times developed recreation areas have been established in older pine stands. Past thinning and tree removals during development have provided ample opportunity for infection. As root rot progresses, many trees become hazardous due to the threat of root system failure.

CONTROL RESPONSE(S)

Prevention and control techniques are available for use against annosus root rot. Granular borax applied as a stump treatment at the first thinning has been shown to be an effective preventive treatment and the competitive fungus Peniophora gigantea Donk. applied at second or third thinnings in infected stands is known to reduce disease severity (Weiss et al. 1978). Prescribed burning before and after thinning decreases disease severity (Froelich et al. 1978) as does thinning during the hottest summer months in the deep south (Weiss et al. 1978). All these techniques are best applied on sites high hazard for annosus root rot; i.e. deep (>12") sandy soils with no restrictive clay layer or high seasonal water table.

With no prevention or control actions taken, annosus root rot will continue to cause significant losses to southern pine plantations. Much of this loss is largely undetected by the forest manager. Quantification of this loss remains to be done on a region-wide basis.

Limited prevention and control techniques for littleleaf disease are also available. Since high-hazard littleleaf sites can be identified by soil characterization, specific sites can be identified and managed with littleleaf in mind. Salvage thinnings of stands over 20 years old is recommended at 6-10 year intervals in order to utilize mortality. Regeneration to the less susceptible loblolly is also used but loblolly too can be affected. Since known soil factors are involved in this disease, subsoiling during site preparation or fertilization (nitrogen) can be very useful in alleviating disease effects. Without utilization of these

methods losses due to littleleaf will continue. Any long-term efforts to rehabilitate eroded, nitrogen-deficient soils will provide long-lasting, positive benefits in reducing disease effects.

Sand pine root disease control remains largely unexplored. The disease was only discovered in the last decade and much about it remains to be learned. Only a few areas of disease management have currently been identified (Barnard et al. 1982) - (1) the possible movement of P. cinnamoni from the nursery to planting sites (this conclusion is yet very tenuous but does offer some future possibility of control or detection in the nursery); (2) during site preparation activities, P. cinnamomi may be introduced on equipment used in other, infected stands (equipment used in P. cinnamomi infested areas should be cleaned of soil before leaving the site); (3) the association of the disease with older, natural stands suggests that a "pathological" rotation may exist and harvesting prior to that age would capture mortality before it occurs; and, (4) proper site and species selection (sites with shallow, fine-textured or poorly drained soils should be avoided; sand pine should probably not be replanted on sites where P. cinnamomi was a problem). Even using these ideas, sand pines will continue to die and decline in growth when infected by one or more root pathogens until more specific control or management techniques can be determined and used.

TECHNOLOGY INFORMATION

Current technology for prevention and control of annosus root rot is probably adequate if conscientiously used. Cost of prevention and control measures are very low. Available technology for littleleaf disease is fairly adequate but the underlying cause of the problem (i.e. abused, eroded, infertile soils) cannot be quickly or easily corrected. Few economical alternatives to loblolly and shortleaf pine exist. Some new technology would be welcome here. Technology for the prevention and control of sand pine root disease is largely non-existent and currently inadequate. Only general, inferential management recommendations can currently be made.

TREATMENT OPTIONS

Annosus root rot

1. Borax stump treatment at first thinning.
   Cost: about 30-50 cents per acre plus labor.

2. Apply P. gigantea at second or third thinning.
   Cost: about $1-2 per acre plus labor.

3. Prescribe burn before and after thinning .
   Cost: about $2 per acre (generally done for other purposes as well).

4. Increase spacing at planting to delay first thinning and decrease total number of thinnings in a rotation.
   Cost: any difference in lost volume production or cost of treatment of additional competing vegetation.

5. Thin during the hottest summer months in the deep south.
   Cost: none.

6. Hazard rate stands according to soil characteristics.
   Cost: (administrative only) $1-2(?) per acre.

Littleleaf disease

1. Salvage mortality at 6-10 year intervals.
   Cost: none.

2. Regeneration to loblolly or hardwoods.
   Cost: none (except hardwoods are not as economically profitable as pine).

3. Subsoiling during site preparation.
   Cost: high

4. Fertilization
   Cost: high

5. Shorten rotation age.
   Cost: none.

Sand pine root disease

1. Shorten rotation age.
   Cost: none.

2. Site selection to avoid sites conducive to *P. cinnamomi* development.
   Cost: little to none.

3. Control *P. cinnamomi* in the nursery.
   Cost: ??

4. Use natural regeneration rather than plant.
   Cost: none, except loss at stocking control and any difference in volume production.

Trends

Incidence and damage due to annosus root rot should increase in the future as the acreage of pine plantations increases (table 1). As these plantations reach thinning age many will become infected without control treatment(s). In talking with pathologists and forest managers it appears that little prevention or control efforts are being made. Of prime consideration is the fact that the forestry community has spent millions of dollars and years of effort developing genetically superior planting stock to grow in plantations. Gains in growth due to genetically superior stock may be totally offset by annosus root rot infections on many sites.

For littleleaf disease the trend appears to be more static. Since the disease is generally tied to existing soil conditions, the affected area is not expected to increase. Conversion of shortleaf stands to loblolly

should produce some gain in volume production along with a decrease in disease severity.

The sand pine root disease situation is likely to worsen in the next decade. Growing interest in planting sand pine in the sand hills of Georgia and South Carolina will probably continue to spread P. cinnamomi, although if proper site selection is utilized (i.e. planting on dry, well-drained sandy soils) the problem might not increase.

OBSTACLES AND LIMITATIONS

There are no known obstacles to the utilization of any existing technology for prevention or control of root disease. Land managers need only an awareness of the problem and the knowledge to apply management alternatives. Some limitations on National Forest land might be encountered in trying to lower the rotation age for shortleaf/littleleaf stands, and, perhaps for sand pine.

QUESTIONS

a. Aging of the forest is not related to annosus root rot but is related to littleleaf and sand pine root disease. In the latter older trees are affected more severely than younger trees.

b. These forest pests are addressed to some degree in the NFs planning process, although, details of disease management cannot all be included in a plan. Flexibility is what is needed.

c. Action against a pest is generally taken when damage becomes visible, dramatic or causes other problems. Often, this is well after substantial growth or volume loss has already occurred.

d. No comment.

e. Answered above.

f. Man-caused changes generally have significant effects upon forest health. All three root diseases discussed here are associated with anthropogenic activities. With annosus root rot, plantation management is strongly related to disease development; with littleleaf, past agricultural practices resulting in widespread severe erosion of Piedmont soils and with sand pine root disease (at least in part) an introduced pathogen (P. cinnamomi) becoming established in forest nurseries and moved onto planting sites (some poorly chosen).

g. Yes, primarily by making forest management more restrictive (e.g. lengthened rotations).

i. Somewhat. In the case of littleleaf, many small agricultural landowners concurrently used abusive farming practices resulting in eroded, worn-out soil. For sand pine root disease, plantation management by forest industry and the extension of the host to the sand hills of Georgia and South Carolina outside its natural range may be contributing to disease abundance.

RECOMMENDATIONS

Further work on root disease problems is needed to clarify certain points especially for sand pine root disease, a relatively new discovery. Many questions remain unanswered; (1) how large is the nursery problem of P. cinnamomi on sand pine?, (2) is this disease being spread to planting sites on apparently healthy seedlings or can diseased seedlings be culled?, (3) to what extent do soil/site factors at the planting site influence later disease development?, (4) is harvesting/site preparation equipment moving P. cinnamomi to uninfested sites?, (5) at what age should mature stands of sand pine be cut to minimize losses to Inonotus circinatus?, and (6) what type of site offers good growth potential for sand pine but minimal root disease risk?

Much more is known about annosus root rot, however, further analysis is warranted in several areas; (1) additional, detailed quantification of growth and mortality losses including economic analyses are needed to document (for land managers) the necessity of addressing this disease, (2) losses on a wide variety of sites need to be quantified, (3) losses of genetically improved plantings need to be examined, (4) the annosus root sampling technique (Dr. Sam Alexander, Virginia Polytechnic Institute, unpublished) for assessing growth losses needs to be further validated and its utility on other than high hazard sites needs to be investigated, (5) are better growth and yield models available which make more realistic projection for smaller geographic areas, (6) can we document volume saved by prevention and control techniques to justify an aggressive control program?, and (7) losses on a regional basis need to be assessed.

For littleleaf disease a number of questions remain unanswered; (1) what rehabilitation techniques can be applied to provide for longlasting improvement in soil conditions (i.e. improved drainage, increased organic matter, topsoil development, increased fertility?, (2) do several short (e.g. 30 yr) rotations of loblolly pine on littleleaf sites provide any rehabilitative effects?, (3) does fertilization enable the manager to use 50-80 year rotations without significant growth and mortality loss?; is the cost justified?, (4) would hardwood rotations provide more rehabilitative effects than pine?, and (5) would a single rotation of hardwoods provide enough benefit to go back to pine?

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Table 1. Acres of pine plantations in southern states as of 1985 and projected acres in 2000.[1/]

	1985	2000
Alabama	2,365,000	4,295,000
Arkansas	990,000	2,516,000
Florida	3,600,000	5,035,000
Georgia	4,270,000	5,530,000
Louisiana	1,475,000	3,086,000
Mississippi	1,724,000	3,021,000
North Carolina	1,614,000	2,615,000
Oklahoma	540,000	778,000
South Carolina	1,961,000	2,582,000
Tennessee	318,000	547,000
Texas	1,595,000	3,458,000
Virginia	1,170,000	1,803,000
TOTAL	21,622,000	35,269,000

1/ **From:** The South's Fourth Forest: Alternatives for the Future. Review Draft. Washington, DC: U.S. Department of Agriculture, Forest Service; 1987. 611 p.

No data on plantations available for Kentucky.

Table 2. Acres of shortleaf pine host in the south with littleleaf disease potential.[1/]

	Survey Date	All Owners	National Forest	Other Public	Forest Industry	Farm	Other Private
Alabama	1973	685,600	29,700	12,300	134,400	183,000	325,900
Georgia	1972	1,730,400	39,400	42,500	234,600	582,100	827,100
Kentucky	1978	40,100	16,500	300	300	8,800	13,200
Mississippi	1973	26,600	0	700	3,500	9,300	13,000
N. Carolina	1975	554,200	2,100	7,400	12,000	284,300	246,700
S. Carolina	1978	612,800	69,800	18,500	116,800	31,000	368,300
Tennessee	1971	122,000	17,500	7,800	7,700	53,800	35,200
Virginia	1976	414,000	0	13,100	70,100	185,700	145,000
TOTAL		4,185,700	175,000	102,600	579,400	1,338,000	1,974,400

Table 3. Acres of shortleaf pine affected by littleleaf disease.[1/]

	All Owners	National Forest	Other Public	Forest Industry	Farm	Other Private
Alabama	228,500	9,900	4,100	44,800	61,000	108,600
Georgia	576,800	13,100	14,200	78,200	194,100	275,700
Kentucky	13,400	5,500	100	100	2,900	4,400
Mississippi	8,900	0	200	1,200	3,100	4,300
N. Carolina	184,700	700	2,500	4,000	94,800	82,200
S. Carolina	204,100	23,300	6,200	38,700	10,300	122,800
Tennessee	40,700	5,800	2,600	2,600	14,600	11,700
Virginia	138,000	0	4,400	23,400	61,900	48,300
TOTAL	1,395,100	58,300	34,300	193,000	442,600	658,000

1/ Mistretta, P.A. Acreage of shortleaf pine affected by littleleaf disease. Rep. 82-2-12. Atlanta, GA: U.S. Department of Agriculture, Forest Service, S.E. Area, State and Private Forestry, Forest Pest Management; 1982. 12 p.

Table 4. Acres of sand pine in southern states.[1/]

	All Owners	National Forest	Other Public	Forest Industry	Other Private
Florida	537,000	202,900	80,900	71,600	181,900
Georgia	15,300	-	-	15,300	*
S. Carolina	*	-	-	*	-
Alabama	*	-	*	-	*
TOTAL	552,300	202,900	80,900	86,900	181,900

Table 5. Acres of sand pine affected by sand pine root disease, 1983.[1/]

	All Owners	National Forest	Other Public	Forest Industry	Other Private
Florida	456,800	172,500	68,800	60,900	154,600
Georgia	11,000	-	-	11,000	*
S. Carolina	*	-	-	*	-
Alabama	*	-	*	-	*
TOTAL	467,800	172,500	68,800	71,900	154,600

1/ **From:** Oak, S.W. Acres affected and losses caused by sand pine root disease, 1983. Rpt. No. 83-1-16. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southern Region, Forest Pest Management, Asheville Field Office; 1983. 7 p.

- = No acreage present in state/owner category.

* = Very small acreage in state/owner category.

Table 6. Number (thousands) and volume (thousands of cubic feet of trees killed by sand pine root disease, 1983. 1/

	All Owners		National Forest		Other Public		Forest Industry		Other Private	
	#	Vol	#	Vol	#	Vol	#	Vol	#	Vol
Florida	12,512	4,113	8,743	2,417	494	245	925	410	2,350	1,041
Georgia	18	1	-	-	-	-	18	1	*	*
S.Carolina	*	*	-	-	-	-	*	*	-	-
Alabama	-	-	-	-	*	*	-	-	*	*
TOTAL	12,530	4,114	8,743	2,417	494	245	943	411	2,350	1,041

1/ Oak, S.W. Acres affected and losses caused by sand pine root disease, 1983. Rpt. No. 83-1-16. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southern Region, Forest Pest Management, Asheville Field Office; 1983. 7 p.

- = No acreage present in state/owner category.

* = Very small acreage in state/owner category.

OTHER PESTS AND DECLINES IN THE WEST

John W. Wenz

The following report is divided into three sections. The first is an introductory narrative that briefly addresses topics that should be considered in developing the initiative. The second is a summary of the responses to the "additional information-obstacles, limitations" and "perceived questions" sections of the standard outline. Pest-specific comments are included in the individual pest responses. The third consists of the individual pest/pest complex narratives submitted by participating Region's in the standard outline format. These include: R-1; white pine blister rust, Douglas-fir beetle: R-2; spruce beetle; R-3; aspen defoliators, pine engraver beetles, spruce beetle: R-5; white pine blister rust, fir engraver complex, western pine beetle complex; R-6; white pine blister rust; R-10; bark beetle complex on Alaskan spruce, western black-headed budworm and cedar decline. The blister rust reports have been consolidated into one narrative.

(1) Introductory Narrative

Following is a brief discussion of some factors that should be considered in developing strategies to enhance and maintain healthy forests in the United States.

1) Prevention/Pest Complexes. Forest pest management recognizes the importance, from both a resource and political perspective, of being responsive to major, extensive, highly visible, pest situations. However, in light of continuing unacceptable levels of pest-related damage and large amounts of money being spent to reduce the losses, it is evident that prevention needs to receive more emphasis. Prevention in this context means evaluating and understanding the complex of factors, past and current, that contribute to an unacceptable situation involving pests, and subsequently implementing (and monitoring) specific actions designed to minimize probabilities of the problem occurring in the future.

Adequate emphasis on prevention will involve non-traditional, less visible, utilization of FPM personnel and, to be most effective, more flexible use of FPM funds. It will also involve more frequent and closer functional contact by FPM specialists with resource managers at the S.O./R.D. level to facilitate integration of pest considerations throughout the site-specific, project-level, resource planning and management process (including implementation and monitoring). More imaginative use of FPM dollars is often needed to make possible the timely implementation of actions (including TSI, pre-commercial thinning, sanitation, other vegetation management actions and early suppression of pest populations to prevent them from increasing to damaging levels) deemed necessary from a pest management standpoint, that cannot be funded in a timely manner through routine resource appropriations. This does not mean that FPM

monies would be used to indiscriminately support resource functions; rather FPM dollars would be available to carry out actions, needed from a pest management perspective, that are beyond the scope of normal resource management activities in terms of the magnitude and/or timeliness of the actions. In essence, this fully integrates pest management with resource management planning and activity implementation by integrating costs of pest management with project cost projections on a site-specific basis. Forest pest management dollars spent in this way should be more than recovered in terms of reduced damage and increased resource production and reduced suppression/salvage costs in the future. This type of FPM interaction with resource management at the project level is essential to begin the process of bringing stands under management while taking pests into consideration and thus significantly preventing/mitigating pest-related damage/impacts.

One reason why this type of FPM activity is needed is that site and project-specific evaluations in California and, increasingly, in other areas in the west, reveal that unacceptable damage is caused by pest complexes, including past management actions, and cannot be effectively dealt with by only treating one component of the complex (e.g. bark beetles). Silvicultural actions will often remedy or prevent a pest problem more effectively than direct pest control efforts. Further, much of the damage occurs as scattered individual or relatively small groups of trees in <1 to 10-15 acre patches which can significantly affect management of specific stands/compartments. Pest complexes have been particularly well documented in California where they are conservatively estimated to be involved in about 80% of the pest-related damage. From a practical standpoint, significant inroads into reducing such damage cannot be accomplished without dealing with these complexes on a site-specific, project-level basis through stand management. This will involve increased use of FPM expertise and resources in non-traditional, perhaps less obvious ways, different from large-scale suppression projects, but should result in significant reductions of pest-related damage.

Emphasizing prevention and bringing stands under sound management should significantly reduce, but not eliminate, pest problems. It will reduce the array of predisposing factors and thus create conditions more conducive for less frequent and limited, but more biologically and cost effective, suppression efforts. There will be a continued need for effective, early warning survey and detection techniques and risk rating systems to predict when and where pest activity is likely to occur. There will similarly be a need for damage/impact evaluation systems and a continued need for effective, environmentally acceptable control techniques.Hopefully, the Forest Health Initiative will include a recommendation for some level of increased support for prevention activties.

2) Regeneration/Young Growth Pests. Preferred alternatives from proposed LMP's in Region 5 from forests that produce significant commercial timber volumes indicate the following trends: a) allocation of lands for a variety of uses other than timber production has resulted in a timber land base of 6.4 million acres which is about a 1 million acre reduction from existing timber management plans; b) approximately half (3.3 million acres) of the timber land base is devoted to intensive timber management but about 3/4 of the ASQ is expected to come from those areas and c) the projected rate of harvest is calculated to deplete all presently standing timber on lands allocated to intensive timber management in 6 to 7 decades. While these figures are specific to R5, the general trend can be expected to be the same in most western regions. Simply stated, the implications for pest (including vertebrate pests) management are a)

since timber management will be expected to produce more volume from fewer acres there will be increased pressure to prevent/reduce pest-related damage on those lands devoted to intensive timber management, b) an increased emphasis on pests of regenerated/young growth stands and c) the need for an objective assessment of the impacts of pest complexes on volume production in these regenerated stands. While we can anticipate to some degree the kinds of pest problems to expect in young growth stands in the west (e.g., grasshoppers, tip moths, shoot borers, reproduction weevils, gouty pitch midge, root diseases, cankers etc.), relatively little specfic information is available on the biology and population dynamics of these potential pests, what levels of damage they might cause under a variety of conditions and management practices,and what kinds of prevention/control techniques might be effective. More intensive management practices can be expected to change the kinds of problems encountered. FPM, FIDR and TM need to work together in the west to begin to provide adequate protection of plantations and young growth stands.

3) Pest Management in Developed Recreation Areas. Forest plans project increased utilization of developed recreation sites and urban-forest interface areas throughout the west over the next 2 to 3 decades. Pest-related deterioration of the vegetation in developed sites in California and elsewhere indicates a definite need for increased pest management activity, including hazard tree management, in such high value areas. The most effective means to accomplish this is to integrate pest management considerations into overall vegetation management plans for developed sites and to provide funding where appropriate and needed. Traditionally, developed site management has been conducted by recreation specialists, landscape architects and engineers focusing on road and facility construction and people management. In general, little effort has been given to vegetation management and non-crisis pest management.

Over the last few years, several successful (at least initially) integrated pest management efforts have been initiated in the west, including the South Shore Recreation Complex on the Lake Tahoe Basin Management Unit in California and Nevada, in various areas on the Arrowhead and Big Bear Ranger Districts on the San Bernardino NF in southern California, and the so-called "High Country" project in Colorado. Most frequently, Recreation and Timber Management dollars are insufficient to initiate and implement vegetation management plans for developed sites. It would be highly beneficial for FPM to make dollars available for use in initiating development of vegetation management plans, including pest considerations, and to provide initial support for implementing needed management activities, including thinning and sanitation. Often, some of the costs can be offset by fuelwood and other sales. This would provide the impetus for subsequent combined Recreation/Timber Management/Fish & Wildlife funds to be made available to maintain the effort on a continuing basis. In any case, the high values associated with the vegetation in heavily used developed sites makes such investments very cost beneficial (although it is difficult to meaningfully quantify amenity values), particularly when the cost of replacement is taken into consideration.

(2) Summary of Responses to Questions

In addition to the information identified required elsewhere in the outline discuss the following:

1. The obstacles, if any, to the use of existing technology for preventing outbreaks of the pest.

a) Inadequate funds and/or lack of flexibility in how (for what purpose) existing funds can be used. Latter can severely limit the effective, timely, use of funds that are available.

b) Shortage of people: We are beginning to see the effects of personnel cutbacks at the RD/SO levels, including postponement and/or cancellation of needed field work and timely pest inputs to management activities at all levels.

c) The combined problems of 1) inadequate numbers of pest management specialists and 2) centralized location of such specialists in locations remote from forests make evident the need for increased, direct, on-the-ground contact by pest management specialists with resource managers.

d) Timber markets/economic conditions often preclude feasibility of implementing needed stand treatments (including recreation areas) and delays bringing stands under management, prolonging susceptibility to pests.

e) The large number of acres/areas that need to be brought under management/treated; i.e., magnitude of problem.

f) Lack of, or difficulty (expense/time/personnel) in, obtaining good damage information.

g) Opposition by some segments of the public to the use of chemicals coupled with an unwillingness on the part of some resource managers to fight controversy.

h) Fear/concern over implementing appropriate management activities in and adjacent to, some management areas i.e., viewsheds, SMZ's etc..

i) Delay in obtaining suppression funds; often, by the time a pest problem has been detected and suppression measures identified, there are quite a number of "hoops" to jump through before funds are made available. Difficulty in predicting when and where damage may occur with sufficient lead time so that management actions, including funding requests and NEPA documentation, can be implemented and effective.

2. The limitations placed on effective response to the pest by laws, policies of the Forest Service, and policies of other government (federal, state, local) agencies.

In general, laws and policies of various agencies are appropriate for objectives of lands being managed. Possible exceptions are deed restrictions on cutting on some land donated to State Parks and some local ordinances which discourage the removal of live trees on private land. It can, at times, be difficult/complicated to implement needed management activities in heavily used, envronmentally sensitive areas (i.e., Tahoe Regional Planning Agency requirements in the Lake Tahoe Basin (restrictions may well be appropriate, but definitely complicate management)). In some situations, e.g., developed recreation areas/urban-forest interface, the problem is more a lack of appropriate ordinances governing proper construction practices, landscape management, vegetation management plans and tree care than inappropriate

existing regulations. Adequate enforcement of, and monitoring compliance with, existing regulations can be a problem also. Policies relating to pest management in and adjacent to Wilderness areas can be a complicating factor. Some people/groups believe that a buffer of minimal or no management of the vegetation should surround each Wilderness; others recognize the need to manage up to the boundary.

3. Perceived questions:

The following nine questions are perceived as influencing forest health and functioning of pests and atmospheric deposition changes. Discuss the relationships, if any, of each of these nine questions, on this pest or on this current pest outbreak.

a. To what extent is aging of the nation's forests related to the incidence of forest pest outbreaks?

Older and overmature trees and stands have been identified as a key factor in bark beetle outbreaks, specifically MPB and spruce beetle. However, to consider age alone is probably an oversimplification of the problem. It is not necessarily age per se that is important, but the fact that as trees (like other organisms) age they tend to become less vigorous and thus increasingly susceptible to bark beetles. This is complicated by how the stands have been managed or not managed. Many old-growth stands have either been unmanaged or mismanaged (high-graded) resulting in overstocked, unhealthy (often with root disease, mistletoe, decay) stands highly susceptible to bark beetles. Properly managed stands (regulated stocking levels, species composition, management of pests) can age in relatively healthy condition, much reducing susceptibility to pests.

b. To what extent do forest plans and the NFS planning process address forest pests and forest health?

Treatment of pest management in EIS's and LMP's varies between regions. In R-10, there is an apparent "reluctance" to incorporate pest management information/input in planning documents with the exception of a few "motherhood" statements. In R-5, FPM is a functioning member of the Regional IDT that reviews all draft and final EIS's and forest plans. Pest management is well integrated into all sections of the EIS's and forest plans for all forests in the Region. Forest-wide and management area direction requires that project plans and site specific EA's/EIS's take pest considerations into account on a case-by-case basis. In certain situations, pest-specific management direction is provided for specific areas.

Integration of quantitative pest data into FORPLAN analyses also varies between Region's. In some situations (e.g., R-1, R-6) where pests, often defoliators, bark beetles and perhaps dwarf mistletoes, affect a significant part of a RD or Forest, pest inputs have been included in FORPLAN analyses. Under other circumstances (e.g., R-3, R-5), timber growth and yield projections take into account a generic "loss" factor which, along with the variability associated the growth and yield estimates, cover pest-specific damage; that is, pest-related and other losses are already built into "conservative" growth and yield projections. Another consideration that needs to be recognized, however, is that frequently, economic, social or other "realities" are built into FORPLAN matrixes that force solutions different than what would have resulted if

"resource-only" (including pests) factors were taken into account. In other words, pest-resource interactions, even if quantified in FORPLAN, can be overridden by other expediencies.

In view of the various controversies surrounding the development and implementation of LMP's, it would seem beneficial that FPM should get together with TM, LMP and other resources as appropriate, on a geographical basis (i.e., the western Regions), to evaluate how pest management is being incorporated into LMP's.

It is our understanding that this question concerning LMP's has already been addressed in some detail by Jim Hadfield at the last Staff Director's meeting and in a report by Dick Fowler.

c. What triggers a decision to take action against a forest pest?

The basic decision-making process (which may result in taking an action against a pest), is initiated when legitimate concern surfaces that pest-related damage is occurring (or is about to occur) that is or will likely result in unaceptable impacts on management objectives. This often results in creation of an IDT that works through the NEPA process to arrive at a decision. The initial concern that starts the process can originate from a variety of sources including resource managers, various public groups and Congress. In some situations, the actual decision to take action, or to implement a particular type of action, is significantlyinfluenced by "political" (in the broad sense) pressure/considerations rather than biological/resource factors.

d. How does the public's knowledge of forest ecology and forest management influence decisions affecting forest health?

The public's knowledge (or lack thereof) of forest ecology/management can influence decisions in different ways. There is a relatively (and understandably) uninformed, often urban oriented, segment of the public that tends to view the forest as static and wants things to be "natural". Timely, well-planned, public information efforts about a particular situation often provide enough understanding about what is proposed and why that the action is either supported or at least not actively opposed. This approach includes involving local groups (homeowners associations, local boards, local governments etc.) and individuals throughout the planning/decision-making process. At the same time, efforts to provide information cannot always overcome or mitigate views of parties with emotional involvement, strongly held feelings based on incomplete information or extreme attitudes retained regardless of the "facts".

In addition, the experience of having gone through an outbreak situation can affect the attitude of individuals/groups the next time the situation occurs; opposition to proposed management action can be much reduced if the experience was positive or "non-action" resulted in unacceptable damage. If the experience was negative, the reverse can be true.

Another aspect of this question is that special interest groups often have access to, or have on their staffs, knowledgeable, professionals who are able to ask good, penetrating questions about proposed management actions, assumptions and conclusions.

e. To what extent does the technology exist for enhancing and maintaining forest health?

In most cases, the technology currently exists and basically revolves around the proper application of sound silvicultural practices (Exceptions are noted under specific pest discussions, e.g. blister rust- improved means of identifying/propagating resistant hosts). Properly managing stands will significantly reduce, but not eliminate, pest problems, reduce the incidence of stress inducing factors, and create conditions more conducive to efficacious pest management. Under these conditions, there may well be a need for more efficient survey and detection capabilities and techniques, stand and tree risk rating systems and environmentally acceptable control techniques such as pheromones.These needs would have to be evaluated on a case-by-case basis.

There is also a continuing need to develop damage/impact assessment technology. Progress has been made in this for some major pests including dwarf mistletoes, spruce budworms, Douglas-fir tussock moth, mountain pine beetle and southern pine beetle. Information is needed for root diseases and, perhaps most importantly, for pest complexes. The technology (data requirements and acquisition techniques, models etc.) must be cost effective to obtain and practical (user friendly) to utilize at the field level. In developing this technology, the real information needs (kinds and level of data accuraccy and precision) at different organizational levels should be taken into account.

f. How have man-caused changes in natural dynamics of the forest ecosystem influencing fire activity, ecosystem diversity, and nutrient cycling affected the incidence of pest outbreaks?

In many situations, effective, long-term fire suppression, often coupled with little or no management, has contributed to creating climax to near-climax overstocked, stressed stands highly susceptible to pests, including bark beetles and dwarf mistletoes. To the extent that large acreages are or have been regenerated with a single species (monoculture), especially following catastrophic fires, there is an increased probability of future outbreaks and regeneration pest problems.

g. How has the increased public involvement in the forest management decision-making process affected forest health?

Increased public involvement is generally perceived as beneficial in that resource managers have the opportunity to clearly explain what they want to do and why (goals & objectives, assumptions, conclusions) and has allowed the "public" to actively participate/provide input to the process. In some cases it has led to compromise and argueably better decisions that reflect how the public wants NF lands to be managed. On the other hand, special interest groups knowlegeable of the process and options open to them, have learned how to use the system to further their particular interest, thus increasing the time and costs associated with implementing resource management decisions.

h. How have public perceptions about pest-caused damages, losses, value of losses, cost of treatment or prevention, and risks of treatment affected forest health?

Effect is probably beneficial in that nationally, there is almost continuous emphasis, and hence continuous interest, in pest-related problems. At the same time, such interest tends to concentrate on a few, very noticeable, wide-spread problems, sometimes located in sensitive areas, at the expense of less obvious, but just as important, situations. Interest often wanes when damage is no longer

evident. This also fosters emphasis (funding) on suppression at the expense of prevention. Many people/interest groups find dead trees objectionable and want to know what is being done about it. Sometimes the same people/interest groups are opposed to most, if not all, resource management activities and/or use of chemicals on general principles. The controversy (or the potential for controversy) discourages some resource managers from implementing needed treatments. These problems can, to an extent, be mitigated via effective public information efforts.

i. How has forest landownership class affected forest health? Do the frequency and intensity of outbreaks by this pest vary by land ownership? What factors explain this difference?

General feeling is that in most cases, land ownership is not a significant factor relating to forest health in the west. Intermingled ownerships can complicate situations by 1) making it more difficult to carry out management actions on an area-wide basis and 2) in urban-forest interface areas, providing circumstances that lead to differing public perceptions of, and questions about, management and/or management objectives on adjacent parcels of land.

WHITE PINE BLISTER RUST

(Cronartium ribicola)

Gregg DeNitto
Sue Hagle
Robert Harvey

Ecosystems and geographic "area covered" in this analysis:

Coniferous forests of California north of Tehachapi Mountains, primarily mixed conifer type; western white pine type in Idaho and western Montana; western white pine and mixed conifer types in Washington and Oregon.

Very brief history and biology of each pest (or group of pests):

Blister rust is a disease of all species of white pines, but is primarily important on western white pine and sugar pine. The fungus must pass through any member of the genus Ribes to be successful.

The blister rust fungus produces aeciospores on the pine host in the spring. These spores are wind-disseminated to Ribes leaves which they infect. A second spore stage, urediospore, is formed on the Ribes leaves and can infect additional Ribes. Later in the summer, a third stage develops which produces teliospores. These germinate in place and form basidiospores. The basidiospores are wind-disseminated to pine needles where they germinate and infect the pine in the fall. The fungus then grows down the branch and can either kill the branch or enter the bole and kill the tree.

Wave years are known to occur with blister rust. The mechanism which causes such increases in infection levels is not known, but it is believed to be related to environmental conditions. These conditions include certain temperature and moisture requirements.

Summarize the current status of the potentially most destructive pests (or group of pests) in the complex.

White pine blister rust was introduced from France into British Columbia in 1910. It was first discovered in Washington in 1921. The first infection in Idaho was discovered on the Coeur d'Alene National Forest in 1923. Since that time it has spread throughout the white pine type in Washington, Oregon, Idaho, and western Montana. It has spread through much of the sugar pine in Oregon and northern California. Accelerated salvage programs beginning in the 20's and continuing to the present have removed nearly all of the old growth western white pine that once dominated the best timber sites in Idaho and Montana. Stands which were once 80-90 percent white pine are now grand fir, cedar, hemlock and Douglas-fir. Stands which contained significant amounts of sugar pine in Oregon have undergone similar species changes.

Of the western white pine type in Region 1, 99+% is infested. White bark pine type may be considerably less infested, more on the order of 10-20%. Approximately 2,670,000 acres are infested. In California, approximately 6.8

million acres of commercial forest land can grow sugar pine (about 40% of the total commercial forest land in the state). Sugar pine does not make up the predominant cover in any forest type, but occurs as individual trees or small clusters of trees. Approximately 80% of the host habitat in California is presently infested by the fungus. The disease can be found or may be expected on about 5.5 million acres. About 95% of the sugar pine and 98% of the western white pine type are infested in Region 6. This comprises about 426,000 acres of sugar pine and 447,000 acres of western white pine.

The infestation started in 1921 in Washington, 1923 in Idaho, and 1929 in California and is not likely to subside for many generations. The fungus requires that the conifer and Ribes hosts be within a few miles of each other. For significant impact to occur the Ribes generally will have to occur within the same or adjacent stand to the white pine. Exceptions are where airflow patterns carry basidiospores from the Ribes to white pine in adjacent stands, over ridges, across drainages, etc. Western white pine and Ribes spp. are nearly always associated.

No change in distribution is expected because nearly all the area within the western white pine type is infested and likely to remain so. The only change that may occur is extension of the infestation in the white bark pine type in the Greater Yellowstone Area, Glacier National Park, Flathead, Custer, and Gallatin National Forests and scattered stands in the Selway Bitterroot Wilderness area. These types are vulnerable although as yet not completely infested.

The "cycle" of the infestation is almost entirely dependent upon the status of the hosts. Salvage of western white pine and sugar pine has resulted in dramatic changes in stand composition with the result of lessening the current level of direct volume loss through blister rust mortality-- the white pine is not there to be killed. Young-growth wild type white pines are being killed at variable rates (depending upon site conditions), but averaging about 60-90 percent before merchantable sizes are reached.

Blister rust was introduced into northwestern California in the 1920's. It spread to the central Sierra by the 1940's. During the past 15 years, blister rust has been spreading south to uninfested areas in the Sierra Nevada. After becoming established in an area, the disease intensifies and appears to increase exponentially in the number of trees it infects. In seedling and sapling-sized trees, mortality usually occurs 5 to 10 years after infection. Pole-size trees may take 15 or more years depending on location of the infection. Sawtimber-size trees usually aren't adversely affected.

Blister rust will continue to infest new areas within the general range of the disease. Any areas harvested and regenerated with sugar pine will likely be infested when the proper environmental conditions occur. The disease will probably be discovered with increasing frequency in the higher elevation white pines. It is not known if the disease will be introduced into the southern California mountains because of natural barriers. However, if the fungus does enter this area it is unknown how it will develop because of different environmental conditions.

Two factors may have resulted in the increase in white pine blister rust. Time is one factor. The second is the increased reliance on clearcutting and regenerating forest land. This has led to an increase in the amount of

susceptible host tissue, both pine and Ribes. Future management that relies on regenerating rust resistant stock in clearcuts will reduce the impact of blister rust. Areas that are managed using shelterwood and selection methods may suffer from blister rust because of the natural regeneration of non-resistant sugar pines.

Presence of the pine and Ribes hosts is sufficient trigger for white pine blister rust. Wave years (seasons in which weather conditions favor extremely high levels of infection) occur about once in seven years in Region 1. So numerous wave years are expected to occur within each rotation. Factors which may have increased pathogen activity include clearcutting, broadcast burning, thinning, favoring species other than true firs, hemlock or cedar, and road building. All of these activities create conditions favorable for Ribes germination and survival.

1,149,620 acres were treated for Ribes population reduction between 1930 and 1959 in Region 1. In some stands this has had the effect of significantly reducing infection levels and increasing survival of white pines, in others, it had little effect. Ribes reduction was practiced on the Mt. Rainier National Park and the Siskiyou and Rogue River National Forests prior to 1967 in R-6. Over 912,000 acres of sugar pine habitat were in control areas during Ribes control efforts in Oregon and California. Reduction efforts were practiced as far south as Sequoia National Forest in California.

Trial treatments with cycloheximide (Actidione) and Phytoactin were done on the Gifford Pinchot, Siskiyou, and Rogue River National Forests, but no operational treatments were done.

Since 1974, rust resistant western white pine has been planted on 14,552 acres in Idaho and Montana and 7,037 acres in Washington and Oregon. Rust resistant sugar pine has been planted on 1427 acres in Oregon. The stock is expected to yield between 30 and 60 percent rust resistance (compared to the estimated 4 percent resistance of wild stock).

285 acres have received treatment by pruning and excising infections in R-1. These methods were used in high-value 15- 30 year old white pine plantations where high infection rates would have left stands non-stocked or unsuitably stocked. About 750 acres have received treatment by pruning alone or in combination with ornamental bough cutting or thinning contracts in R-6.

The only feasible control methodology in California at present is the use of rust resistant stock. There have been minimal attempts at this with only a few hundred acres at most having been planted. Only a fraction of a percent of the total infested area have received this type of treatment. Increased efforts at identifying resistant parent trees and collecting seed will increase the amount of use of this method in future years.

Describe the expected accumulative impacts associated with this complex of infestations or infections

The overall impact of this disease is the loss of two of the primary species for regeneration. Western white pine has been reduced from the primary timber resource of R-1 to a minor associate of mixed conifer stands. Western white pine and sugar pine have been reduced to a significantly

lesser component in associated mixed conifer stands in R-6. Only when additional resistant parent trees are identified and seed collected will sugar pine again become a viable species in northern California.

Specific impacts

Regions 1 and 6

The most productive white pine type is found on the Clearwater National Forest and adjacent private timber lands. Here the old growth white pine was salvaged and a largely cull grand fir/cedar understory was left. These sites generally are producing less than 30 mbf/acre at maturity where the same sites stocked with white pine at maturity are expected to produce 70-90 mbf/acre. On Idaho Panhandle National Forest white pine sites the standard replacement for western white pine is Douglas-fir. A projected loss of productivity using Douglas-fir in a pure stand compared to western white pine in a pure stand is approximately 40 mbf/acre at rotation age (90 years). In addition to differences in stand productivity, the product value is much higher for white pine as compared to all other second-growth species alternatives. Western white pine is currently selling for $80-120 on the stump while Douglas-fir, the next highest, is fetching $10-50 stumpage rates.

The situation is compounded by vast acreages of salvaged lands which are badly in need of harvest and regeneration but yield such low values as to be unsaleable. Each year these lands go untreated increases the productivity loss.

Where resistant white pine are planted, planting costs are incurred. These are most often situations in which natural regeneration of western white pine could have been attained at no cost above site preparation. Planting costs are usually $100-200/acre. The cost of producing rust resistant stock is very high if research and development expenses are considered. A continuing program of testing new parent trees to maintain genetic diversity in the resistant stock is also both neccessary and costly.

In R-6, average stumpage prices for white pine and Douglas-fir are similar, but vary depending on the location of stands. White pine stands on the east side of the Cascades average $65/mbf and on the west side average $152/mbf; Douglas-fir averages $34/mbf and $149/mbf, respectively.

Region 5

Plantations on mixed conifer sites are regenerated with a mix of species. The loss of sugar pine means that other species will have to be planted in higher proportions. Some of these species, such as white fir and Douglas-fir, are of a lower value and will provide a lower return at harvest if present relative valuations continue. Stumpage values ($/mbf) in 1986 were: sugar pine-$167, ponderosa pine-$157., Douglas-fir-$64, and white fir-$42. There will be no loss of existing timber value over the next decade because this is primarily a pest of regeneration. Similarly, no change in recreation values are anticipated. It is unknown if any wildlife are specific to young-growth sugar pine, but if there are, the loss would likely be minimal. An indirect cost in recreation areas will be the inability to regenerate areas with an alternative species. Regenerating sugar pine was an effective pest management tool in mixed conifer stands

where dwarf mistletoe in other species was a concern. Similarly, sugar pine was an effective replacement in annosus root disease centers in true fir.

Control Response(s)

Regions 1 and 6

All white pine sites should be hazard rated to determine the need for specific treatment. Various levels of rust resistance have been achieved in planting stock. This variety of stock should be matched to the level of hazard on each site so that the available resistance is fully utilized.

Status of blister rust infection in each stand with second-growth white pine should be measured. Stands which would benefit from intermediate treatment should receive treatment and those commercial stands which are losing volume at an unacceptable rate should be harvested and regenerated.

Much could be done to reduce Ribes populations both by silvicultural methods and by direct control using herbicides. Reducing Ribes populations would allow lower resistance levels to succeed on some sites. Use of planting stock with lower resistance would make more seed and stock available (highest resistance stock is currently in short supply). It also would tend to lessen the chances of super races of the pathogen developing by reducing selection pressure.

Recovery of western white pine is slowly proceding in the "wild" population. Selection is yielding an estimated increase of 1-2 percent resistance per generation over the wild population. At 60-90 years per generation it will take many centuries to attain a fair level of resistance. Changes in the pathotypes of the fungus will be occurring during this time as well so that the net change in resistance is not reliably predictable.

Although it is unlikely that future "infestations" are preventable, the level of damage could be greatly reduced using well-timed treatments on a routine basis. In addition to using resistant stock which is matched to site hazard, Ribes populations could be maintained at low levels using low-disturbance logging and site preparation methods. Species mixes which result in rapid stand closure and timing of thinning to increase shading pressure on plants would benefit not only the current rotation but future rotations as well by reducing seed production. Pruning and, occasionally, excision could be used to bring marginally stocked stands through to economic maturity. These techniques are only useful when appropriately timed so regular monitoring of high-value western white and sugar pine stands would be necessary.

Region 5

There are no direct control actions presently available other than regenerating resistant stock. If no action is taken, the infestation will continue to worsen and very little sugar pine will be available for harvest after the present inventory is depleted in 5 to 6 decades.

Technology Information

Technology to reduce future infections is being refined. Screening for resistant trees is the key to the future of sugar pine. Efforts are presently underway to increase our abilities and capabilities to screen increasing numbers of seedlings.

Additional technology is needed in two areas. The present mechanism for breeding resistance in sugar pine, single gene resistance, is susceptible to being overcome in time by the fungus. This mechanism is viewed as only a short-term relief until broader based resistance mechanisms are defined and cultivated. Work needs to continue into identifying and cultivating additional forms of resistance. There may be some differences in site hazard in the state. These are poorly defined and need to be explored to determine if a hazard rating system may be feasible.

Treatment Options

Technique - Regenerating resistant planting stock. This requires identifying resistant trees, collecting seed, and planting. In addition, efforts at producing seed orchards of this genetic material must continue.

Cost of treatment - It is estimated that approximately $250 are needed to identify each parent tree with major gene resistance in California. This does not include research and development costs. The value of the seed from each parent is $75/pound. Other undefined costs include altering timber sales to avoid/protect identified resistant trees and the cost of altering tree improvement attempts at increasing timber yields by requiring that trees also be resistant.

Technique - Pruning and excision of cankers. Infected trees are pruned to remove infections and susceptible tissue. Bole cankers are excised to limit the spread of the fungus and stop it from girdling the tree.

Cost of treatment - $60/acre. Pruning alone would probably cost considerably less but would have to be closely timed to be effective in a single treatment if, in fact, a single treatment will be sufficient. Pruning can be costly or produce income depending on the local markets. The Gifford Pinchot NF has successfully combined pruning operations with sale of ornamental boughs collected in the fall.

Technique - Ribes control. The amount of Ribes in a stand is reduced through site preparation and vegetation management. There is no data to support the efficacy of this treatment or to determine the cost.

Technique - Early harvest. Infested stands are harvested prior to optimum rotation to reduce mortality losses. Some loss in revenue by harvesting stands prior to culmination and from reduced value of smaller logs.

Discuss the observed and expected trends of the next decade for these pests.

Regions 1 and 6

The white pine type is being converted to mostly Douglas-fir and grand fir mixed conifer stands. Some white pine is slowly being introduced back into the type as resistant stock. Most wild white pines are dying before reaching pole-size. This pattern is likely to continue. A few wild-type white pine plantations have been treated to reduce lethal infection and a

few more will probably be treated over the next decade. Most white pine plantations established in the 1960's are dying and will be gone within the decade without treatment. Stands in the white pine type are generally being allowed a small percentage of wild white pine. Some of these can be expected to reach maturity but the white pine will not significantly affect the stand productivity or value in such low numbers.

Region 5

White pine blister rust will increase in intensity in areas where it presently exists. It will virtually eliminate sugar pine from most plantations less than 20 years old. The sugar pine component that is pole-size will decrease in plantations and natural stands. Fewer regeneration options will be available over the next decade. New areas that aren't infected will become infected and reduce the acreage of sugar pine.

Obstacles to the use of existing technology

Insufficient amounts of resistant white pine and sugar pine seed are available for planting. Funding needs to be made available to identify resistant parent trees and to operate an effective screening program. Insufficient funding is available for pruning and excision projects. Demonstrations of these techniques need to be available for examination. Testing of silvicultural control techniques is inadequate.

3. Perceived questions:

The following nine questions are perceived as influencing forest health and functioning of pests and atmospheric deposition changes. Discuss the relationships, if any, of each of these nine questions, on this pest or on this current pest outbreak.

Regions 1 and 6

a. Aging: Not much affect. Most of the white pine type has been cut over in the past 80 years. The disease affects all ages and is most quickly lethal in young trees. The alternate host, Ribes, benefits from site disturbance and is much more prevalent in the cutover areas.

b. Forest plans: Blister rust is poorly addressed. Only use of resistant stock is considered.

c. Decision: District silviculturists are responsible for treatment decisions.

d. Public: The local public has not been involved in treatment decisions although any proposal to reduce Ribes populations using herbicides would surely be met with considerable opposition and, at this time, legal complications.

e. Technology: The technology for managing white pine blister rust largely exists. Transfer and application of existing technology is slow to develop.

f. Human-caused changes: Human activity has greatly affected the population levels of both hosts of white pine blister rust. Site disturbance increases Ribes populations, fire exclusion may effectively decrease populations where no harvest activity occurs, harvest of western white pine with discrimination against the species in regeneration has greatly reduced populations of this

species. The "outbreak" of white pine blister rust is still with us but the economic host largely is not.

g. Public involvement: Probably not a significant factor. Forest Service decision-makers are in many cases skeptical of white pine blister rust management owing to the abandonment of the species in the 1960's. It has been a slow process to convince managers to invest in another program of blister rust management.

h. Public perceptions: Few of the public currently knows of or is concerned with white pine blister rust, specifically, but in general the local public tends not to believe that action is neccessary to control forest pests. People believe that the trees have always been there and that if we leave them alone they will always be there. Local understanding is more that trees die when they are harvested or when wildfires kill them.

i. Land ownership: For the most part this has no effect on white pine blister rust. The exception would be Potlatch Co. timberlands in Idaho. The company has considerable holdings in Idaho white pine type. They have a fairly aggressive program of blister rust control which includes use of resistant stock in planting and chemical control of . The company considers western white pine to be their most valuable species in their inland operation. In all probability they have a lower intensity of infection in their white pine than does the Forest Service and they regenerate a much higher proportion of white pine than does any other forest land owner in Idaho (or Montana).

Region 5

a. To what extent is aging of the nation's forests related to the incidence of forest pest outbreaks?

Aging of the nation's forests does not influence this disease.

b. To what extent do forest plans and the NFS planning process address forest pests and forest health?

Forest plans address blister rust in a general format by recognizing its presence and possible influence on management activities.

c. What triggers a decision to take action against a forest pest?

The dramatic increase in the incidence of blister rust in California over the past 10 years has resulted in an increase in the desire for resistant planting stock and a reduction in the planting of "wild" stock.

d. How does the public's knowledge of forest ecology and forest management influence decisions affecting forest health?

The public does not have the ecological knowledge to understand that clearcutting without adequate vegetation management may be aiding the increase in blister rust. Continued public pressure to limit herbicide spraying may further increase the incidence of blister rust.

e. To what extent does the technology exist for enhancing and maintaining forest health?

Much of the technology exists for identifying individuals with single gene resistance and producing planting stock from these individuals. Technology is limited in producing trees with any form of multiple gene resistance. Technology does not exist in California for evaluating blister rust site hazard.

f. How have man-caused changes in natural dynamics of the forest ecosystem influencing fire activity, ecosystem diversity, and nutrient cycling affected the incidence of pest outbreaks?

Being introduced, the disease is human-caused in the U.S. to begin with The increase in site disturbance has increased the Ribes population and altered microsites, thereby increasing rust incidence. The planting of sugar pine in some situations at higher proportions has also influenced the disease.

g. How has the increased public involvement in the forest management decision-making process affected forest health?

Although the effectiveness of herbicides on disease reduction is uncertain, the public's limitations on their use may have caused some increase in rust in local situations.

h. How have public perceptions about pest-caused damages, losses, value of losses, cost of treatment or prevention, and risks of treatment affected forest health?

Some very local publics notice when blister rust enters a new area, but they are a vast minority. Most publics are unaware and apathetic to a disease like blister rust which does not cause dramatic "overnight" changes in the forest.

i. How has forest landownership class affected forest health? Do the frequency and intensity of outbreaks by this pest vary by land ownership? What factors explain this difference?

Landownership does not influence blister rust.

Recommendations

Further analysis needed: One of the greatest needs in this area is economic analysis of the various management techniques. We need to know when a procedure is and is not likely to be economically feasible.

We also need a better understanding of the effects of silvicultural systems on Ribes populations. We need to know the effects of certain silvicultural treatments on blister rust incidence and if alternative treatment methods are available.

In Region 1, we have a prototype model of white pine blister rust effects on stands which needs to be linked to growth and yield models. Considerable testing of this model is also needed.

Added information needed: The status of white pine blister rust in white bark pine has not been evaluated since the 1960's. With the new interest in white bark pine as an essential grizzley bear habitat component, there should also be a renewed interest in white pine blister rust in white bark pine.

A model must be created to hazard rate stands in the absence of western white or sugar pines. This might be linked to one or more key indicator plants and should be developed at the District level because of the considerable variation between sites.

In Region 5, we need to document if site characters may influence rust incidence sufficiently for us to develop a predictive system.

Actions needed now: Initiate an economic analysis of management techniques and follow up with funding for special project to treat stands as justified.

Expand options of using western white and/or sugar pine in Phellinus weirii infection centers and frost problem areas.

Determine site characters that may influence rust incidence and develop a site hazard rating system for California.

Continue to select potentially resistant sugar pines for screening and increase quantity of resistant seed in seed bank.

Actions needed within five years: Incorporate expanded treatments in Forest plans.

Continue development of alternative resistance mechanisms and incorporate into tree improvement program.

BARK BEETLE COMPLEX ON ALASKAN SPRUCE

Edward Holsten

As with other regions, there is a variety of pests in Region 10 (Alaska) that affect forest health and could be considered for discusssion. In view of extent of damage, economic considerations, and "regularity" of damage, the following pests (complexes) will be discussed below: (1) Spruce beetle (*Dendroctonus rufipennis*) and engraver beetles (*Ips perturbatus*) which will be discussed as a pest complex on spruce; (2) Black-headed budworm (*Acleris gloverana*) on western hemlock; and (3) Cedar decline affecting tens of thousands of acres of Alaska yellow cedar.

I. Geographic area, history and biology of pest, and current status of outbreaks:

The spruce beetle is the primary tree-killing insect in Alaska and is prevalent south of the Alaska Range. On-going as well as new (as of 1986) infestations now cover approximately 370,000 acres throughout Alaska. North of the Alaska Range, Ips beetles are the primary tree-killing insect although outbreaks are much less common than those of the spruce beetle. At times however, scattered, but intense Ips activity has encompassed more than 1,500 square miles. Presently, Ips infestations of white spruce encompass more than 17,000 acres in interior Alaska.

Preferred hosts for both insects are large diameter (>8" dbh), slow growing white spruce (*Picea glauca*), Lutz spruce (*P. x lutzii*), and Sitka spruce (*P. sitchensis*). Black spruce (*P. mariana*) is rarely attacked. Commercial hemlock-Sitka spruce type occupies 5,506,000 acres mainly in southeast Alaska's coastal forests. Historically, Sitka spruce is less susceptible to spruce beetle outbreaks than either white or Lutz spruce. Cool, wet spring conditions, so prevalent in southeast Alaska are not conducive to spring beetle dispersal and brood development. However, currently there are approximately 20,000 acres of Sitka spruce infested by spruce beetle. Commercial white spruce stands (including Lutz spruce) occupy approximately 10,000,000 acres in Alaska; predominately in southcentral and interior Alaska. As previously mentioned, it is the white spruce type that has supported the majority of Ips and spruce beetle outbreaks. Climate is more continental and thus, more conducive to beetle build-up and brood development.

The majority of spruce beetle outbreaks have originated from some type of forest disturbance such as blow-down, cull logs, improper slash disposal resulting from seismic exploration or powerline right-of-way. However, such conditions do not necessarily mean that an outbreak will develop. The standing green timber must be of large diameter and of low to poor vigor. If these conditions are present and weather (especially early spring) is favorable, an outbreak will start. The same goes for Ips beetle outbreaks. Of those outbreaks that have been documented, the majority have originated from flood damaged (stressed) spruce, stands which have suffered broken tops or blowdown. Likewise, Ips outbreaks will develop only when the residual standing trees have poor vigor. Spruce beetle outbreaks, once started, are aggressive and can remain active in a stand for as much as ten years although most outbreaks die down by the sixth year. Ips outbreaks build-up quickly but rarely last more than three years.

The spruce beetle normally has a two year life cycle. However, in southeast Alaska, where climate is less conducive to beetle development, a generation may take as long as three years. On the other hand, in white spruce stands which have southerly aspects, especially those in southcentral Alaska, spruce beetles may complete a generation in one year. Ips beetles normally have a one year life cycle with new adults as the overwintering stage. However, it is believed that Ips may complete more than one generation per year in interior Alaska.

Spruce beetle activity increased throughout Alaska during 1986. Substantial spruce beetle caused mortality has appeared for the first time north of the Alaska Range along the Yukon River south of Galena. This "new" infestation is expected to encompass close to 80,000 acres this year and will probably expand over the next few years. Approximately 100,000 acres of infestions occur on the Kenai Peninsula. However, the majority of these infestations, which occur in white and Lutz spruce types are at least five years old and are decreasing as the beetles have depleted the majority of the susceptible host material. The 14,000 acre spruce beetle infestation in southeast Alaska (Glacier Bay National Park) is decreasing. We expect an overall spruce beetle activity throughout southeast Alaska. On the other hand, the spruce beetle has been building up in recent years in the Sitka spruce stands throughout the coastal zones of the Kenai. Infestations will probably increase in these areas for the next few years. Overall, we can expect an increase in beetle activity throughout interior Alaska as thousands of acres of white spruce sustained blowdown last winter.

The 17,000 acre Ips beetle outbreak near Fairbanks is expected to expand for the next year or so and then decline. Ips perturbatus, the causal agent, is an aggressive Ips species, attacking mature white spruce from the lower bole to the top of the tree. Beetles attack early in the spring and needle drop occurs by August of the same year. We can always expect Ips caused mortality throughout interior Alaska. However, the majority of the outbreaks occur in inaccessible areas and are normally not of much concern. However, the

Fairbanks outbreak is occurring in white spruce stands that have road access. Likewise, 8,000 acres of the outbreak occurs within the Bonanza Creek Experimental Forest managed by the Institute of Northern Forestry (PNW).

Stand conditions in Alaska are presently very conducive to bark beetle infestations. With the continuation of the fire suppression "philosophy", many white spruce stands are now overmature and of poor vigor. Incidence of heart and root rots is high. Consequently, trees are very susceptible to wind breakage. Thus, availability of brood material is increasing. The majority of the spruce stands in Alaska are inaccessible and consequently outbreaks are allowed to run their course. Up until now, little or no stand management has occurrred even in those stands that are accessible by roads. This is most apparent on the Kenai Peninsula. Limited salvage logging has occurred but in no way has reduced the infestation levels nor has salvaged the majority of the beetle infested timber. Chugach National Forest Management objectives are recreation and wildlife oriented. They are beginning to realize that vegetative management, which may incorporate thinning green stands, will greatly reduce the potential of beetle build-up in their "high-valued" stands. A few land managers (State and private) are incorporating trap tree programs to reduce beetle impacts on their lands. However, the acreage being treated is low compared to the acreage which is presently impacted. Homeowners in the Anchorage Bowl have been using preventive insecticide treatments on a regular basis for the past five years. The Chugach National Forest will undoubtedly be using insecticides in their high value campground and administrative sites where white and Lutz spruce occur.

II. Accumulative Impacts:

A. General: 1. Hastening of successional changes; many spruce stands are rapidly being converted to climax Mtn.Hemlock stands. Mtn. Hemlock has little economic value. 2. Decrease in value of timber as local market for beetle killed timber is presently low. Higher "value" for green, uninfested timber but Chugach National Forest is only into salvage logging. 3. Potential increase in wildlife (moose) habitat as beetle infested stands are opened-up allowing browse vegetation to increase in occurence and percent cover. 4. Increased fire hazard in beetle infested stands. This presently is a very important issue in south-central Alaska especially on the Kenai Peninsula where there are a number of small communities surrounded by thousands of acres of standing beetle-killed timber.

B. Specific Impacts: The Chugach National Forest has spent the last twelve months in an indepth planning process (Operation Resource Renewal) to determine the extent and the impacts of the spruce beetle on NFS lands. The Decision notice should be signed off shortly and the implementation process initiated. Specific impacts have been identified and will be briefly mentioned here: 1. Fire hazard has greatly increased; 2. Recreation values have been negatively impacted; 3. Timber values lost; and 4. In some

cases, wildlife (moose) habitat (old growth forests which are used as winter range) have been negatively impacted. Fire hazard will continue to increase over time as much of the beetle killed timber starts to windthrow thus increasing the fuel load on the forest floor.

III. Control Response(s):

In high value young growth stands, precommercial thinning would greatly reduce the potential for future beetle infestations. Some selective cutting is proposed for a number of green stands on the Chugach N.F. which have a high risk of becoming infested. A number of incipient infestations could be "controlled" through the juidicious use of conventional and lethal trap tree programs. Salvage logging is not a realistic "control measure" as local and export markets are not presently available to absorb the present amount of beetle killed timber. And as previously mentioned, much of the impacted timber is inaccessible.

Throughout much of the State, present infestations will be allowed to run their course and future infestations will occur. As previously mentioned, large amounts of blowdown occurred last winter throughout the range of white spruce. The potential for increased beetle activity over the next ten years is quite high.

Research and managment direction is presently directed towards prioritizing and determining high-value stands, and risk-rating these stands as to their potential for spruce beetle outbreaks.

IV. Technology Information:

A. Spruce Beetle: Life cycle information well understood and good information pertaining to host(white spruce)/insect interactions as well as good information on factors influencing stand (white/Lutz spruce) susceptibility. Specific needs include refinement of present risk-rating system; development of a practical and registered lethal trap tree program, and development/refinement of silvicultural prescriptions to reduce beetle impacts. Studies are needed to delineate the semio-chemical complex of the spruce beetle. Preliminary studies have shown a potentional for the use of anti-aggregant compounds in preventing spruce beetle build-up in down material. Information on lifecycle, behavior and stand dynamics are need for Sitka spruce stands as recent evidence has shown that knowledge gained from white/Lutz spruce studies is not totally applicable to the coastal hemlock-Sitka spruce stands.

B. Ips Beetle: Life cycle information is fairly well known but more studies are needed on factors responsible for two generation/year populations. Studies are need to delineate the pheromone complex of the species involved. Silvicultural prescriptions are needed if interior white spruce stands come under management. The feasibility of using conventional and lethal traps should be explored and a risk rating system developed.

V. Treatment Options:

Many of the treatment techniques have been previously described and include such traditional measures as: Lethal and conventional trap trees, carbaryl and lindane preventive sprays, salvage logging and selective cuts. There is little or no information concerning cost of treatments.

VI. Expected Trends of Bark Beetle Complex:

As previously mentioned, increases in both Ips and Spruce beetle are expected for the next decade due to the quantity and extent of recent blowdown. Increases in spruce beetle infestations are expected on the Kenai Peninsula especially in the high volume, coastal Sitka spruce stands.

VII. In Addition to the Information........:

1. One obstacle is the "environmental" public's reluctance to use chemicals for the prevention of spruce beetle attacks on high value trees such as found in campgrounds and around administrative sites. However, in many cases, this is the same "public" which readily sprays the spruce in their yards.

2. The delay in obtaining suppression funds. In many cases, by the time the pest problem has been perceived and suppression measures have been laid out there are quite a number of "hoops" to jump through before funds are available.

3. Perceived questions:

a. Without a doubt, this is one of the primary reasons behind our current Alaska bark beetle problems. Reluctance to harvest timber in southcentral Alaska as well as the inaccessibility of the majority of the white spruce stands in interior Alaska as well as increased efforts at fire suppression have allowed Alaska's white and Lutz spruce stands to overmature.

b. For some reason, there has been a "reluctance" in the planning effort to incorporate Forest Pest Management information and input other than a few "motherhood" statements. However, the Chugach National Forest is "actively" dealing with the spruce beetle problem through their planning process but it maybe to late to realistically deal with the problem.

c. Public and Congressional pressure and inquiries--unfortunately, it's not a management decision.

d. The public's knowledge is "understandably" low on these subjects. However, after a good Public Information effort--there is more backing for sound forest management. However, we're out of "sinc" in that we get into a situation where a problem surfaces with a pest, then we go into a Public Information campaign--then we deal with the pest. However, during the this whole process, the pest increases in population levels and damage and gets "out of hand". We need to initiate Public Information early in the process.

e. The technology is there---sound silvicultural practices. However, the economic situation or public perception holds us back.

f. As previously mentioned, increased fire suppression and minimal timber harvest over the last 50 years or so has contributed to interior and southcentral Alaska's non-vigorous spruce forests. Also the public prefers to recreate in "old-growth" forests and demands that we maintain these old-growth, low-vigor forests in a healthy state. A difficult situation to deal with.

g. I think it has helped tremendously. However, we need to initiate public involvement much earlier in the process, not after a pest has reached outbreak status.

h. Overall, public knowledge of pest conditions in Alaska has increased and this has helped in the planning process. However, as previously mentioned, public demands "old-growth" forests for recreation and expects the Forest Service to maintain these areas in a pest free situation. Difficult task to accomplish.

VIII. Recommendations:

Further analysis and information needed: With respect to Alaska, we need more information on the impact of the spruce beetle on resources other than timber. There is a paucity of information with respect to beetle related impacts on recreation, wildlife, fisheries habitat. Without such impact information, the majority of the Forest's EA's and EIS's are appealed (and many are successfully appealed) as they only address timber values which, in many of southcentral Alaska's spruce stands, are marginal at best.

WESTERN BLACK-HEADED BUDWORM

Acleris gloverana (Walsingham)

Edward Holsten

I. Geographic area, history and biology of pest, and current status of outbreaks:

Coastal Sitka spruce - western hemlock forests in southeast Alaska

Distribution: Throughout southeast Alaska and Prince William Sound (southcentral Alaska). Western hemlock (*Tsuga heterophylla* Raf. (Sarg.)) is preferred host; Sitka spruce (*Picea sitchensis* (Bong.) Carr.) is secondary. Western hemlock covers 70% of forested area.

Life cycle: Insects overwinter in egg stage. Larvae emerge in May-June, feed until late July-early August; pupate in August for two weeks. Adults emerge in August-September, lay eggs on host foliage.

Cycles and triggers: Infestations roughly on 10-12 year cycles, triggered by climatic conditions.

Status of infestation: Currently very low throughout southeast Alaska.

Percent of host occupied: Less than 1%.

Acres occupied: 200

Probable course: Upward.

When could it start: Started in 1986.

Future expectations: Unknown.

Infestation triggers: Warm, dry summer followed by warm, dry fall would favor population increase.

Possible responses: Might include chemical treatments in seriously affected areas, although this has not been done since the early 1960's when DDT was applied.

II. Accumulative Impacts:

A. General impacts: Growth loss, occasional top-kill caused by heavy defoliation.

B. Specific impacts: One previous outbreak resulted in net volume losses of 7000 board feet per acre where hemlock was the dominant stand component in an old-growth forest. In young stands, top-kill was noted in most dominant and codominant spruce and hemlock. Similar losses could occur in certain areas within the next decade.

III. Control response:

Infestations rise and fall depending on weather, and defoliation is intense for only one or two years. An infestation would probably not be of sufficient duration to warrant chemical treatment. If no action is taken, some growth loss and/or top-kill would result, but total stand effects are not clearly known. Infestations probably cannot be prevented since regional climate, rather than biotic factors, dictates the frequency and magnitude of the infestations.

IV. Technology information:

The relationship between population levels and weather is fairly well understood. The effects of stand stocking, species composition, and stand age have not been thoroughly investigated in Alaska. However, the Canadians are more concerned with budworm in young stands than old stands because it causes so much top-kill.

V. Treatment options:

None have been employed since 1962

VI. Trends-next decade:

Populations may increase from present endemic levels.

VII. In Addition to the Information..........:

3. Perceived questions:

a. Trees in old-growth forests appear to be more heavily defoliated than younger trees.

b. Not to a very great extent

c. The clear evidence of extensive tree discoloration or mortality

e. It doesn't

f. Hard to say since we haven't had an outbreak in the last 25 years

VIII. Recommendations:

More information is needed on stand susceptibility and/or ability of different types, ages of stands to withstand budworm damage. Also, need information on what levels of damage occur.

ALASKA-CEDAR DECLINE

Edward Holsten

Alaska-cedar Decline is one of the most conspicuous forest maladies in Alaska; over 200,000 acres currently have dead and dying trees. The principle tree species affected is Alaska-cedar (*Chamaecyparis nootkatensis*).

I. Ecosystems and geographic area covered in this analysis:
Alaska-cedar decline affects forested stands throughout southeast Alaska (the panhandle). Forest types with poorly drained, deep organic soils have the greatest incidence of mortality.

Brief history and biology of each pest:
Distribution: Alaska-cedar is distributed from the southern portion of southeast Alaska to Prince William Sound in the Gulf of Alaska. Acreages this forest type are not known. Decline affects stands from throughout most of southeast Alaska, but does occur further northwest than Cross Sound near Chichagof Island and Glacier Bay.

Life cycle: The primary cause of Alaska-cedar decline is not known; but organisms (e.g., pathogenic fungi, bark beetles, etc.) play secondary roles in causing mortality. Recent research, however, indicates a sequence of symptoms from early stages of decline to tree death: fine root death, necrotic lesions on larger roots, necrotic lesions at the root collar that spread up sides of the bole, loss and discoloration of foliage. Trees are frequently, but not consistently, attacked by *Armillaria* sp. and bark beetles (*Phloeosinus* spp.).

Summarize the current status of the potentially most destructive pests (or group of pests) in the complex:

Status of infestations: Alaska-cedar trees die every year, as they have since about 1880, in stands affected by decline.

Percent of host type affected: Most of the Alaska-cedar type in southeast Alaska is affected.

Acres occupied: Over 200,000 acres of decline are currently mapped in southeast Alaska.

Probable course of infestation:
When did it start: About 1880.
Where did it start: Synchronously throughout southeast Alaska.
Future distribution: Alaska-cedar decline spreads slowly (about 1 meter per year) on sites where it began in about 1880. Spread to new sites does not occur. Therefore, decline will continue to show slow encroachment on forest stands adjacent to stands with mortality, but will probably not appear on new sites.

What might cause or trigger an infestation? The primary cause of decline is not currently understood. Research indicates that decline may have "natural causes" (not influenced by human activity) that may include changes in the development of the deep, wet, organic soils where decline occurs. A warmer climate since about 1880 could be responsible for changes in soil development. Secondary factors include: *Armillaria* sp., *Phloeosinus* sp., *Cryptosporiopsis* sp., *Cylindrocarpon didymum*, and other fungi. Human activities, including forest management, probably have no significant affect on the origin or development of decline in southeast Alaska.

II. Describe the expected accumulative impacts associated with this complex of infestation:

General impacts: Loss of harvestable volume, altered wildlife habitat, increased use of resource by public, increased research on resource.

Specific impacts: Loss of grade and volume of Alaska-cedar because affected stands are not typically salvaged. Loss of confidence for future management of Alaska-cedar. Visual impact of numerous stands of dead trees to the public. Increase use of cedar for firewood. Altered or improved (for some species) habitat for wildlife species. Decline has triggered research on ecology of Alaska-cedar.

III. Control responses:

What action could be taken to control this infestation? Salvage stands with a high volume of dead and dying trees. Research may indicate that Alaska-cedar can be regenerated on these sites.

What would happen in no action is taken? Volume of dead Alaska-cedar will be lost as trees slowly decay and deteriorate.

What could be done to prevent future infestations? Probably nothing. Intensive control could include altering soil drainage in affected stands.

IV. Technology Information:

Describe the adequacy of available technology to reduce impact: Studies demonstrating the feasibility of salvaging stands of dead Alaska-cedar have not yet been conducted.
Describe technology needed to reduce impact: Information is needed on the volume and grade reduction of Alaska-cedar trees that have been dead for various lengths of time. Also, we need to determine the best means of reforesting any stands that are salvage-logged.

V. Treatment Options:

To date, no treatment has been conducted in southeast Alaska.

VI. <u>Discuss the observed and expected trends of the the next decade for these pests:</u> Alaska-cedar decline spreads slowly (about 1 meter per year) on sites where it began in about 1880. Spread to new sites does not occur. Therefore, decline will continue to show slow encroachment on forest stands adjacent to stands with mortality, but will probably not appear on new sites. Areas of decline will increase quite slowly over the 200,000+ acres currently affected.

VII. <u>In addition to the following information identified required elsewhere in the outline, discuss the following:</u>

1. The obstacles, if any, to the use of existing technology for preventing outbreaks: The remote location associated expense in logging will limit the economics of salvaging affected stands.

2. The limitations placed on effective response to the pest by laws, policies of the Forest Service, and policies of other government agencies: Research on salvaging and regenerating stands of dead Alaska-cedar are placed on low-priority in Region 10.

3. <u>Perceived questions:</u>

a. Alaska-cedar can be one of the longest-lived of all tree species. Although decline occurs old-growth stands, stand age is probably not an important predisposing factor.

b. Plans do not include increasing activity to reduce losses from Alaska-cedar decline, nor do they include funds for research on salvage logging or regeneration of Alaska-cedar.

c. Typically, interest from the District-level (e.g., District Ranger) triggers action.

d. Public opinion is taken into consideration, although generally, the public generally has a superficial understanding of forest ecology and management.

e. Research is needed to develop technology to reduce impact and loss from Alaska-cedar decline.

f. Human activities have had very little impact on the onset and development of Alaska-cedar decline in southeast Alaska. This fact makes this disorder a very interesting contrast to the dozens of other forest declines where humans probably have some form of causal role.

g. Increased public involvement has, in many instances, turned the attention by the Forest Service from forest health to more controversial issues such as the volume of harvest, wildlife habitat, and subsistence in our Region.

h. Public opinion has not focused on Alaska-cedar decline, even though it is one of the most conspicuous types of mortality in the region and occurs throughout southeast Alaska.

i. The vast majority of acreage of Alaska-cedar decline is confined to the Tongass National Forest, primarily because this forest encompasses most of southeast Alaska. In terms of proportional impact, decline does not vary by ownership and also occurs on State, Private, and Native land.

VIII. Recommendations:

Research Alaska-cedar decline including studies on the etiology, impact on plant and animal communities, salvage opportunities, and regeneration on affected stands must continue now and over the next several years if we can expect to manage and utilize this valuable resource.

DOUGLAS FIR BEETLE

(Dendroctonus pseudotsugae Hopkins)

Jed Dewey

Area Covered: Northern Region (Montana, northern Idaho, Yellowstone National Park)

Background:

Distribution -

Throughout range of Douglas-fir in the Northern Region

Preferred hosts -

Douglas-fir (occasionally felled western larch)

Acres of Commercial Host Type by Ownership: (Douglas-fir only)

Forest Service	Other Federal	Industry	Other Private
3,649 M	831 M	482 M	1,735 M

Outbreak cycles and triggers -

DFB infestations usually occur in trees damaged by windfalls, fire-scorch, or defoliation. Tree susceptibility to attack is correlated with drought and root disease.

Attack behavior and damages -

The attack is initiated from April through June by the emerging overwintering adult beetles. Some adults that flew in the spring re-emerge and make a second attack usually in late June or July. Large-diameter, mature, or overmature trees are usually attacked.

Damages vary markedly from year to year depending on the occurrence of outbreak generating events, e.g., windthrow, fire, etc..

Current Situation

Douglas-fir beetle activity is at a relatively low level in the Region at the present time. In 1986, about 6,300 trees, containing about 2 million board feet, were killed by the DFB on approximately 4,500 acres. This means that less than .001 percent of the host type is currently infested.

We do not anticipate another major DFB outbreak until a catastrophic event triggers a rapid population buildup. These events (e.g., blowdown, fire, severe drought, heavy defoliation, etc.) are not predictable.

Impacts

Number of acres affected -

Four thousand, five hundred acres were recorded with DFB-killed trees in 1986 in the Northern Region. This number has fluctuated from a high of about 12,000 acres to a low of about 1,000 acres during the past decade. This represents between .6 and 7 million board feet killed per year during this time span. A large-scale outbreak in northern Idaho killed over 100 million board feet of Douglas-fir from 1970 through 1973.

What Caused the Outbreak

The primary cause of a DFB outbreak is the preponderance of old-growth Douglas-fir in the Region, much of which is root diseased and decadent. These stands are susceptible to severe losses when an outbreak is triggered.

Current Control Programs

Conversion of old-growth Douglas-fir stands to young, vigorous, mixed-species stands is the primary long-term control approach being used. Rapid salvage of blowdown, fire-scorched trees, heavily defoliated trees, etc., does much to prevent a rapid population buildup. In areas where rapid salvage is not realistic, infestation of this material can be prevented by aerially applying the antiaggregating pheromone MCH.

The last, and only, time that MCH has been used operationally in this Region to prevent a DFB outbreak was in 1984 when about 2,400 acres of inaccessible Douglas-fir blowdown were treated. This was about 10 percent of the total blowdown area. The remaining area was immediately salvage logged.

Stand management activities that discourage root disease, defoliation, or mature host trees will help prevent future infestations.

Technology Information

Available technology for the management of the DFB is limited largely to salvage activities and prevention of a population buildup in susceptible material with the use of MCH.

Needed technology includes:

1. A proven risk-rating system for predicting when and where outbreaks can be expected.

2. Stand management practices that can alter a stand's susceptibility to beetle attack.

3. Proven techniques using attracting pheromones for concentrating populations so they can be suppressed via traps, logging, spraying, etc.

Treatment Options

The only DFB direct control approach being used in Region 1 is MCH.

In 1984, 2,400 acres were aerially treated with MCH for $142,000 or $59 per acre.

Expected Trends

As long as there are extensive stands of mature and overmature Douglas-fir in Region 1, there will be periodic DFB outbreaks that will be triggered by disturbances of one sort or another. Intensity of the outbreaks will be related to extent of the disturbance, timing of the disturbance, subsequent management activities, climatic conditions, etc.

Additional Information

1. The main obstacles to the use of MCH are:

    1. High cost of materials and application.
    2. Limited availability and quality of application equipment.

2. MCH is still not registered with the EPA even though application for registration was submitted over 2 years ago. To date, projects are conducted under the authority of an experimental lease permit and/or a special local needs registration.

3. Questions

a. Losses to DFB are directly related to aging of the nation's forests. Old forests are more subject to conditions that trigger outbreaks, and the outbreaks themselves are limited to old, large diameter trees.

b. Forest Plans address this pest only indirectly, as when they deal with replacing old decadent stands with young, thrifty ones.

c. Action on DFB is usually triggered by a catastrophic event such as extensive windthrow or fire. Forest industry then often forces direct action to be taken.

d. Public knowledge is so limited regarding the DFB that it has had little or no effect on management decisions.

e. The technology is present to enhance and maintain forests where DFB would be of little consequence. Limiting factors include:

    1. Extent of old-growth Douglas-fir.

    2. Agency constraints (e.g., size of clearcuts, riparian zones, etc.).

    3. Land classification restriction (e.g., wilderness areas, scenic areas, wildlife areas, etc.).

f. Man-caused changes have created a condition favorable to the DFB. Fire suppression and concentrated harvesting of seral species have led to increased acreages of Douglas-fir. These activities have led to more frequent and intense

Douglas-fir beetle outbreaks, and perhaps an increased incidence of root disease. These are important factors related to DFB losses.

i. Landownership and subsequent management philosophies do not have a serious bearing on losses to the DFB. This is because infestations do not "sweep" across extensive areas once they have begun. They build up in the vicinity of a disturbance, persist for 2 or 3 years, then return to their endemic level. Thus, except for lands immediately adjacent to one another, a landowner is not significantly impacted by an outbreak on another ownership.

WESTERN PINE BEETLE

Dendroctonus brevicomis, Complex

Dennis Hart

Ecosystems and geographic "area covered" in this analysis:

Ponderosa pine and mixed conifer types in California.

Very brief history and biology of each pest (or group of pests):

Distribution:

The western pine beetle occurs throughout host type (ponderosa pine and mixed conifer type) in the west; tends to be most important in California; also Oregon and Washington.

Description of host vegetation:

Normal attack and development occur only in ponderosa pine, *Pinus ponderosa*, and Coulter pine, *P. coulteri*.

What percent of the area covered is occupied by host vegetation:
Hosts occur over approximately 9.3 million acres or 58% of the total commercial forest land in California.

Life cycle:

Western pine beetles pass through the egg, larval, pupal, and adult stages during a life cycle that varies in length from about 2 months in warm weather to 10 months in cool weather. All stages are completed beneath the bark of infested trees, except for a brief period when the adults fly to find new trees to attack.

In California there are typically from two to three generations of beetles per year, with attacks as early as March and as late as November.

When the female beetles successfully attack a tree, they release minute amounts of behavioral chemicals into the air. These odors (pheromones) attract males and other females to the tree, causing a mass attack that tends to overcome the tree's natural resistance. If numerous beetles are in the area, and fair weather persists, adjacent trees may be attacked, resulting in a group of infested trees. Usually, an insufficient number of beetles in the area, or bad weather delays the arrival of more beetles to the vicinity of the newly attacked tree. Either of these conditions will result in the occurrance of isolated dead trees, rather than large groups of mortality.

Besides attracting western pine beetles themselves, the pheromones also attract their natural enemies, such as the predaceous checkered and ostomid beetles. The ability of these beetles to sense the pheromones of the western

pine beetle potentially makes them effective preditors during the critical attack phase.

Cycles and triggers:

Outbreaks of the western pine beetle occur periodically. Usually, the beetles breed in slow growing trees, 6 inches in d.b.h. and larger, in overstocked stands in association with the occurance of other pests, such as root rots (Annosus root disease, _Fomes annosus_; black stain root disease, _Verticicladiella wagnerii_), western dwarf-mistletoe, (_Arceuthobium campylopodum_), and trees injured by pine engraver beetles (commonly _Ips paraconfusus_), lightning, logging injury, ozone and fire injury.

Typically the western pine beetle attacks slow growing trees, and can cause serious group mortality in dense, over-stocked stands of pure, even-aged pine where it can kill the dominant and co-dominant crown class trees.

The usual trigger for serious mortality is severe drought, combined with slow tree growth, injuries in the stand, and the build up of other pest conditions in the stand, predisposing trees to western pine beetle attack.

Summarize the current status of the potentially most destructive pests (or group of pests) in the complex.

Status of infestations: Generally static but beginning to increase as drought conditions continue.

Percent of host is occupied: Describing western pine beetle (and other bark beetle) activity in California at this time in terms of % host type and acres occupied is difficult because the mortality occurs throughout the host range as scattered, individual trees and small groups of mortality rather than in readily definable areas of contiguous mortality. Past Pest Damage Inventory and 1975-77 Drought Survey data indicate that under "normal" conditions, western pine beetle mortality levels are about .05 trees/acre while during outbreak periods, the figure is about 1 tree/acre or greater.

Probable course of the infestation

When could an infestation start?: Most likeley during the next drought; California is currently experiencing significantly below normal precipitation.

Where might it start?: The next outbreak will probably start in overstocked ponderosa pine stands which are weakened by injuries and infected with other disease conditions, such as root rots and dwarf-mistletoe. The trees likely to be attacked first will be over 6 inches d.b.h., have reduced growth rates and weakened by injuries and/or disease. Such trees are important to the ecology of the western pine beetle, since under "normal" conditions they are the type of trees attacked and in this way, the western pine bettle is able to perpetuate its population by breeding in weakened trees when the general stand conditions are unfavorable to an increase in its numbers.

What are the expectations about future outbreaks: Periodic outbreaks can be expected in conjunction with drought conditions.

Where will it be (area and cycle) in 1988, 1990, ten years?: It has been extremely dry in California for the past two years. If this dry trend continues, tree mortality caused by bark beetles will increase. When moisture conditions return to normal, bark beetle associated mortality will decline to endemic levels within two to three years. In California, seriously dry conditions tend to occur in ten year cycles.

What might cause or trigger an infestation?: See above. Outbreak cycles of tree mortality associated with the western pine beetle are triggered by periods of drought, together with adverse stand conditions, such as overstocking severe enough to cause a decline in tree growth, tree injuries, and the build up of other pests in the stand.

Describe the current control measures: An integrated pest management approach is being implemented utilizing detection, evaluation, prevention and suppression activities as appropriate and feasible. Currently, no direct control actions are being taken; actions being taken (generally not specifically for western pine beetle alone) include normal salvage operations and silvicultural treatments prescribed on a site specific basis. Salvage operations can be expected to increase as mortality increases.

Accumulative impacts

General impacts: Impacts will vary depending on management goals and objectives and from a potential action/treatment perspective, need to be evaluated on a stand/site specific basis. From a timber production standpoint, to the extent that there is a viable market for pine, western pine beetle associated mortality can result in dollar loss through reduction of merchantable volume. Meaningfull, overall, quantitative estimates are not readily available. Some of this loss can be offset by salvage sales. Additional impacts can include contributing to understocked stands and increased fire risk.

Recreation- Western pine beetle can have a significant negative impact on developed recreation areas depending on the proportion of host trees in the stand. Mortality can result in unwanted openings in campgrounds and other developed sites, increased numbers of hazard trees and consequent increased management (removal) costs, reduced shade and secreening and generally a reduced "quality" of the vegetation which can result in lowered quality of the recreational experience. Difficult to quantify many of these impacts meaningfully.

Wildlife- To the extent that the amount of "old growth" is reduced and increased importance is placed on specific old-growth areas or stands, pine mortality in such areas could potentially affect old-growth dependent species (i.e., spotted-owl). At the same time, some positive impacts will result including creation of snags and downed logs. Wildlife impacts are site specific and hard to quantify.

Specific impacts: Limited real losses under endemic conditions. Possible severe losses during epidemic periods during severe drought conditions. The severity of impact during these epidemic periods will be directly proportional to the condition of the stands, the poorer the health of the stands the higher the losses can be expected to be. Expected changes in yield per acre would be about 100 bd.-ft. per acre per year.

Control Response(s)

What actions could be taken to control this infestation?: Although any of several direct control actions could be implemented to kill brood in individual trees, it is generally not efficacious or practical (biologically/economically) to control area-wide infestations through direct control alone.

What would happen if no action is taken?: There would continue to be an accumulation of overstocked, injured, and diseased stand conditions that would result in increased tree mortality and growth loss per acre thru time.

What could be done to prevent future outbreaks?: Prevention best accomplished by bringing stands under management, regulating stocking levels, species composition, etc., taking into consideration insects, diseases and other pests in the pest complex. Specific actions include pre-commercial and commercial thinning, TSI, release and timely harvest.

Technology Information

Describe the adequacy of available technology for prevention or reduction of outbreaks: Generally adequate.

Describe technology needed to prevent, reduce, or control future occurrences of these outbreaks: Thinning and TSI treatments.

Treatment Options

Describe treatment techniques, accomplishments and costs

Technique (describe): Pre-commercial thinning.

Frequency of use: Once during the life of a stand.

Accomplishment (includes losses averted): The final volume will be similar to no action, but this volume will be on less stems of higher value and better form, with more uniform spacing. The stands will be in better condition.

Total acres treated by year: Ave. 12,000 acres/year.

Acres benefiting treatment on other acres.: Almost none.

Cost of treatment per acre:

Biomass harvest with Feller/buncher	$0 - 20/acre (Administrative $)
Commercial fuelwood	$0 - 20/acre (Administrative $)
Contract thinning	$200/acre

Technique (describe): Commercial thinning

Frequency of use: Ave. every 20 years from age 40 to 80

Accomplishment (including losses averted): Some volume removed earlier which increases value. Increased commercial volume due to rapid growth rate and volume concentrated on fewer stems. Commercial thinning in eastside pine has reduced pest-caused losses by about 110 bd. ft./ac/yr.

Total acres treated by year: Ave. 2,500 ac/yr.

Acres benefiting from treatment on other acres: Low. Adjacent acres may receive some benefit from breaking stand continuity.

Cost of treatment per acre: Generally returns $ to Treasury (Ave. $28,000 MBF sold).

Technique (describe): Sanitation harvest (High Risk)

Frequency of use: As needed

Accomplishment (include losses averted): Remove potential center of group kill before attack occurs. Recover green value of individual trees (usually 3-4 times salvage value). Prevent mortality of 1-10 surrounding trees. May remove source of dwarf mistletoe infection. May be some increased growth and vigor due to slight thinning.

Total acres treated by year: Ave. 22,000 a/yr.

Acres benefitting from treatment on other acres: Benefits extend to 1/10 acre or less around each tree removed.

Cost of treatment per acre: Generally returns dollars to Treasury (ave. 92,500 MBF sold).

Technique (describe): Preventive spraying for western pine beetle (carbaryl).

Frequency of use: As needed for approx. 1 year protection.

Accomplishment (includes losses averted): Primary benefit of retaining ornamental or recreational trees during periods of temporary, reversable stress (drought, fire scorch). Generally used only where a value of several hundred dollars can be assigned to an individual tree for resources other than timber. May be some benefit to adjacent trees if group kill can be avoided.

Total acres treated by year: NA- individual trees.

Acres benefitting from treatment on other acres: Additional 1-10 adjacent trees may benefit if grouip kill avoided.

Cost of treatment per acre: $3-10 per tree.

<u>In addition to the information identified required elsewhere in the outline discuss the following:</u>

1. The obstacles, if any, to the use of existing technology for preventing outbreaks of the pest.: Shortage of funds and personnel, low value of some species and size classes, lack of awareness of techniques, and other work of higher immediate priority.

2. The limitations placed on effective response to the pest by laws, policies of the Forest Service, and policies of other government (federal, state, local) agencies: In general the laws and policies of the various agencies are adequate for the land being managed.

3. <u>Perceived questions:</u>

The following nine questions are perceived as influencing forest health and functioning of pests and atmospheric deposition changes. Discuss the relationships, if any, of each of these nine questions, on this pest or on this current pest outbreak.

a. To what extent is aging of the nation's forests related to the incidence of forest pest outbreaks?: Older trees are often more susceptible to attack by WPB than are younger trees, but all host trees to a limit of about 300 years are capable of being nonsusceptable to WPB attack if they are not stressed. Basal area increases as the stands age, making them subject to the stress of overstocking, if they are not silviculturally treated.

b. To what extent do forest plans and the NFS planning process address forest pests and forest health?: Plans address pests and forest health in a general way. Some specifics in the AMS, Project plans and site

specific EA's should address stand conditions and pests on a case-by-case basis.

c. What triggers a decision to take action against a forest pest?: The concern of local land managers, or the public, that management objectives cannot be accomplished dure to the pest impact, will cause the creation of an ID team to work through the NEPA process. Selection of an alternative by the line officer may trigger a decision to take action against adverse pest conditions.

d. How does the public's knowledge of forest ecology and forest management influence decisions affecting forest health?: Often the public view is too biased for "natural" forest conditions which leads to adverse stress through overstocking and the gradual build-up of pest conditions in the forest stands. Generally, first there is the build up of disease conditions, such as root rots. The last stages of this decline are signalled by the occurrance of bark beetle mortality in the stands. Often these pest conditions are "natures" way of silviculturally treating these stands.

e. To what extent does the technology exist for enhancing and maintaining forest health?: The technology exists---which is sound silvicultral practices. However, the economic situation, and at times the public perception holds us back.

f. How have man-caused changes in natural dynamics of the forest ecosystem influencing fire activity, ecosystem diversity, and nutrient cycling affected the incidence of pest outbreaks?: Widespread long term fire supression has allowed basal area to build and brush to encroach, which stresses early successional stages (pines) and speeds succession. Large monocultures of pine plantations set the stage for future outbreaks.

g. How has the increased public involvement in the forest management decision-making process affected forest health?: In some cases this has caused delays and seriously delayed reaction time to the point where it has negated any benifit that could be hope to gain through treatment. Often it has lead to compromises, but at times this has been benificial. In some cases this has lead to more rational decisions to be implemented.

h. How have public perceptions about pest-caused damages, losses, value of losses, cost of treatment or prevention, and risks of treatment affected forest health?: Often the vocal majority of the activists oppose logging/ or the use of pesticides for any purpose. This opposition has caused intense controversy in certain instances. At times there has been enough controversy that some land managers have dismissed worthwile treatments because they felt that the public would never accept the treatment, or they have accepted compromises that would provide no beneficial results. In general public involvement needs to be included earlier in the planning process.

i. How has forest landownership class affected forest health? Do the frequency and intensity of outbreaks by this pest vary by land ownership? What factors explain this difference?: On those lands where

the stands or silviculturally treated and sanitized there or fewer problems associated with the western pine beetle.

Recommendations

Further analysis updated: No.
Added information needed: Possibly, a western pine beetle anti-aggregation pheromone identified, tested and registered.
Actions needed now: Additional funding for thinning and TSI.
Actions needed within 5 years: Same as above.

FIR ENGRAVER

Pest Complex: Fir Engraver, *Scolytus ventralis*, Complex

John Wenz

Ecosystems and geographic "area covered" in this analysis: Coniferous forest ecosystems throughout the west containing fir host type; analysis emphasis on California.

Very brief history and biology of each pest (or group of pests):

Distribution

Description of host vegetation (preferred and secondary):

The fir engraver attacks most true firs in western forests; most common in white fir, *Abies concolor*, grand fir, *A. grandis*, and red fir, *A. magnifica*; occasionally found in alpine fir, *A. lasiocarpa*, Douglas-fir, *Pseudotsuga menziesii*, mountain hemlock, *Tsuga mertensiana* and Engelmann spruce, *Picea engelmanii*.

What percent of the area covered is occupied by host vegetation: In California, fir engraver hosts grow on approximately 7.4 million acres of commercial forest which is about 46% of the total commercial forest land in the state.

Life cycle:

The fir engraver, *Scolytus ventralis*, attacks most true firs from pole-size to over-mature in the western United States. Fir engraver attacks can result in a) mortality, b) top-kill and/or c) patch or strip-kill along the bole. It can take from 1 to 2 years to complete a life cycle. Adults fly and attack hosts from June through September; larvae, pupae and adults can overwinter. Pitch tubes are not formed and attacks are characterized by boring dust in bark crevices along the trunk and pitch streamers on the mid and upper bole. Trees successfully attacked early in the summer may exhibit fading of foliage by early fall, but those attacked later in the year will not begin to fade until the following spring/summer.

Cycles and triggers:

A number of factors contribute to fir engraver-related outbreaks and damage. Basically, increases in fir engraver activity develop in trees/stands that are or become stressed. Unhealthy, less vigorous, hosts have reduced growth rates (an indication of reduced vigor) resulting in reduced host resistance to fir engraver attack.

A number of predisposing factors have been associated with fir engraver activity. These include 1) sub-normal precipitation- *Scolytus* activity has been correlated with precipitation of at least 11% below normal in the outbreak and preceeding year and/or a 32% reduction in the current (outbreak) year precipitation; 2) Logging- fir engraver mortality has also been correlated with logging history. Increased mortality is associated with past selective harvest that removed high proportions of the most vigorous dominant and co-dominant

trees leaving the suppressed and intermediate (most susceptible) hosts. Fir engraver can attack and reproduce in slash and, to the extent that such material is not treated in a timely manner, engraver populations can build up and contribute to subsequent damage to residual trees. Past selective logging in the mixed-conifer type that removed the most commercially valuable species (mostly pine) has, through time, resulted in an increase in shade-tolerant species (firs) and thus an increase in the amount of host material, often in an unmanaged, overstocked condition. This has also occurred in the CA eastside pine type where Jeffrey pine has been removed from many sites, allowing white fir to occupy what are really pine sites. In short, these factors have tended to increase the susceptible food base and resulted in conditions conducive for fir engraver activity.

In addition to management (and lack of appropriate management) practices and site and stand conditions, several insects and diseases contribute to the fir engraver "pest complex". The most important are annosus root disease, Fomes annosus, Phellinus Weirii root rot and true fir dwarf mistletoe, Arceuthobium abietinum. Others include true mistletoe, Phoradendron bolleanum ssp. pauciflorum, the Douglas fir tussock moth, Orgyia pseudotsugata, the white fir needleminer, Epinotia meritana, and budworms, Choristoneura sp..

In essence, all of the above predisposing factors (biotic, abiotic and management actions/inactions) contribute singly and in combination to creating conditions conducive to fir engraver activity resulting periodically, in increased tree and stand damage. The exact combination of factors will vary on a case-by-case basis.

Summarize the current status of the potentially most destructive pests (or group of pests) in the complex.

Status of infestations or infection:

Fir engraver associated mortality/top-kill/patch-kill in CA has increased over the last 2 to 3 years in conjunction with below normal precipitation over most of the host type. White fir needleminer activity also increased in localized areas in 1986-87.

Percent of host is occupied:

Describing fir engraver (and other bark beetle) activity in California in terms of % of host type and acres occupied is difficult because the activity occurs throughout the range of the host as scattered, individual, trees and small groups of mortality/top-kill rather than in readily definable areas of contiguous mortality. Past Pest Damage Inventory and 1975-77 drought data indicate that under "normal" conditions, the fir engraver complex mortality levels are about .05 trees/acre while during outbreak periods, the figure is approximately 1 tree/acre or greater.

Acres occupied:

See above; difficult to quantify meaningfully.

Probable course of the infestation or infection:

Fir engraver outbreaks occur at irregular intervals; there has been at least one per decade in CA and OR since 1925. The current increase in fir engraver

activity started in 1984-85 and can be expected to continue for another 2-4 years depending on levels of precipitation. Periodic outbreaks can be expected in subsequent decades.

When could an infestation or infection start?

See above; just about any time when predisposing conditions exist; particularly likely during/after periods of drought.

Where might it start?

See above; areas where predisposing site/stand/pest complex factors exist.

What are the expectations about future distribution and extent.
See above; similar to current distribution; periodically increasing in extent.

Where will it be (area and cycle) in 1988, 1990, ten years? See above; essentially the same areas; periodic increases in numbers.

<u>Describe the expected accumulative impacts associated with this complex of infestations or infections</u>

General impacts: Impacts will vary depending on management goals and objectives and from a potential action/treatment perspective, need to be evaluated on a stand/site specific basis. From a timber production standpoint, to the extent that there is a viable market for fir and that the trees are otherwise sound from a product viewpoint (not often true with fir), fir engraver associated mortality and top-kill can result in dollar loss through reduction of merchantable volume. Meaningfull quantitative estimates are not readily available. Some of this loss can be offset by salvage sales. Additional impacts can include contributing to understocked stands and increased fire risk.

Recreation- Fir engraver can have a significant negative impact on developed recreation areas depending on the proportion of host trees in the stand. Mortality can result in unwanted openings in campgrounds and other developed sites, increased numbers of hazard trees and consequent increased management (removal) costs, reduced shade and secreening and generally a reduced "quality" of the vegetation which can result in lowered quality of the recreational experience. Difficult to quantify many of these impacts meaningfully.

Wildlife- To the extent that the amount of "old growth" is reduced and increased importance is placed on speicfic old-growth areas or stands, fir mortality in such areas could potentially affect old-growth dependent species (i.e., spotted-owl). At the same time, some positive impacts will result including creation of snags and downed logs. Wildlife impacts are site specific and hard to quantify.

Specific impacts: Specific, quantitative impacts generally not available.

<u>Control Response(s)</u>

What actions could be taken to control this infestation or infection?

Although any of several direct control actions could be used to kill brood in individual trees, there is no practical way to control area-wide infestations through direct control alone; best action is prevention.

What would happen if no action is taken? Mortality and top-kill will continue to occur periodically, increasing through time.

What could be done to prevent future infestations or infections?

The most effective means of prevention is to bring stands under management, regulating stocking densities, species composition, using genetically sound trees etc., taking into consideration insects, diseases and other pests (the pest complex).

Technology Information

Describe the adequacy of available technology for prevention or reduction of infestations or infections.

Basically, the means/technology needed to reduce impacts of this pest complex is currently available. In essence, they include well-established silvicultural and stand management techniques and practices implemented in a timely manner.

Describe technology needed to prevent, reduce, or control future occurrences of these infestations or infections.

Bringing stands under sound management will significantly reduce, but not eliminate, pest problems. It will, if done properly, significantly reduce the array of predisposing factors and thus create conditions more conducive for efficacious management (control) of the fir engraver and other in fir stands (pest complex). This would entail the need for effective survey and detection techniques and stand risk rating systems to predict when and where increased pest activity is likely to occur. This could well involve pheromone systems which will require increased research and development in the case of the fir engraver. Similarly, from a control standpoint, there will be a need for environmentally acceptable techniques; pheromones are a good candidate in this regard and research is needed with respect to developing mating disruptant, trap-out and anti-aggregation application technology (the latter would be particularly useful in developed recreation sites and urban-forest interface situations).

Treatment Options

Treatment option discussion essentially same as for western pine beetle except that there are no chemicals registered for use against the fir engraver; therefore, direct control and preventive treatments using chemicals are not currently options.

In addition to the information identified required elsewhere in the outline discuss the following:

Discussed above; nothing specific to fir engraver not covered under general response.

3. Perceived questions:

Discussed above; nothing specific to fir engraver not covered under responses to the nine questions in the introductory narrative.

Recommendations

Further analysis needed
Added information needed: Pheromone research/development.

Actions needed now: Increased/more flexible use of funding/personnel to accomplish prevention; perhaps pheromone R&D.

Actions needed within 5 years: Same

SPRUCE BEETLE

Spruce Beetle, Dendroctonus rufipennis(Kirby)

Robert Averill

I. Geographic area, history and biology of pest, and current status of outbreaks:

Engelmann spruce, Picea engelmannii, Parry, serves as the primary host for the Spruce Beetle(SB) in Region Two. In a severe outbreak it will attack adjacent non-host trees, but this is rare. The distribution of spruce/fir type in Region Two is:

Species	National Forest	Other Public	Forest Industry	Private Owner	Withdrawn/ Noncommercial
			SOUTH DAKOTA		
Spruce/fir	18.4	0.7	0.7	4.5	0.7
			WYOMING		
Spruce/fir	676.7	63.4	2.1	28.6	951.5
			COLORADO		
Spruce/fir	2584.8	60.4	2.5	351.7	1564.0

The SB is not found in South Dakota, but on the other 6.2 million acres of spruce type in Colorado & Wyoming, this insect has been a major entity. Creating additional concern is the fact that of the 4.2 million acres administered by the Forest Service, 29 percent or 1.2 million acres is withdrawn, primarily in Wilderness areas. Probably 70 percent of the spruce/fir type is in a moderate or higher risk category to the beetle on all ownerships.

A two year life cycle is the norm within the Rocky Mountain Region. Generally outbreaks originate from an accumulation of windthrown material, or from poor harvest management practices which allows the buildup of large diameter logging debris, or failure to remove infested material in a timely manner.

II. Accumulative Impacts:

A. General: Depending upon the severity of the outbreak and its location a variety of impacts occur. On available lands, sale schedules and harvest regimes are thoroughly disrupted, creating impacts all the way through the sawmill operations. Future partial cuttings are hampered by standing dead and down timber, increasing operating costs. On unavailable lands with severe outbreaks, an increase in the fuel loading, increased wildlife habitat, and increased water yield are the first major impacts. As time moves on, down timber reduces forage availability, clogs trail systems, and increases hazards from falling trees during windy periods.

B. Specific Impacts: The last outbreak in standing timber was on the Rio Grande National Forest(1980-1985) within a Sale Area that was harvested in the 1960's. A windstorm created scattered downtrees throughout the leave unit areas. Salvage logging was not rapid, nor complete enough to reduce the

suitable down material before a flight to standing trees took place. In order to maintain future options throughout the area, salvage of infested trees as well as the first step of a shelterwood system were implemented in the drainage. Risk to beetles was lowered within two beetle flights through an aggressive treatment program. Largescale impacts were minimized, though the next entry will probably result in somewhat less volume per acre than desired.

III. Control Response:

In the Rio Grande outbreak, appropriate control response was done in a timely manner. Had the treatments not been conducted in a timely fashion, many more acres would have been affected. When this outbreak started, the Region was just implementing its Resource Information System(RIS) which contains risk rating sub-routines for Stage II data. Now, nearly all Forests have risk ratings on all recent inventories. This information is being used to prioritize treatments on available land.

A. Technology Information: The biology and ecology of SB is well understood in the Region. Technology is adequate to manage the insect. Application of the technology is limited by markets, accessibility and competing demands for how the land will be managed. Refinement of the present technology will be needed as more spruce/fir stands are brought into a managed condition. These refinements relate to stocking control and attractiveness to SB.

B. Treatment Options: The primary treatment option begins with adequate monitoring of the spruce type annually through detection surveys and sale administration of active sales. Trap trees are used when a buildup of beetles is noted in down material. The use of pheromones to attract SB to log decks has also been used with success in experiments. Further pilot testing is warrented prior to operational use. Depending upon severity of the infestation, $5-10/ac has been an adequate treatment cost by FPM to augment the costs over and above a normal sale. Should treatment by direct chemical control become necessary the expected cost would be be in the $20-25/tree range, assuming that Lindane will be available when the next need occurs.

IV. Expected Trend for the next decade:

We expect SB activity to increase during the next decade, especially on lands in the Wilderness System. Our ability to respond to the insect on available lands will only be constrained by adequate detection, access, and markets.

V. In addition...:

A. Obstacles to the use of present technology are primarily related to markets for the available material. With adequate markets, there would be a higher demand for spruce, creating greater competition in the marketplace, resulting in bid premiums, and increased logging efficienies. This would then enhance the implementation of two & three step shelterwood systems which would result in very little spruce beetle mortality from this level of intensive management.

B. Perceived limitations for effective response to SB associated with law and policies of various government agencies relate to how people expect the forest to look and their expectations for a variety of goods and services to flow from these lands. The greatest limitation, in my opinion, relates to

the question of wilderness. Some people believe that a boundry of minimal or no management of the vegetation should surround each Wilderness area, others recognize the need to manage right up to the boundry. We have experienced both viewpoints with the public.

VI. Nine questions answered:

1.The aging forest plays a significant role in SB activity. The "good" side of the issue is that with a two year life cycle, a preference for down material, we have a longer window to determine a course of direction. On the "bad" side is the aspect that a significant area of spruce/fir will be allowed to run its natural cycle creating a threat to adjacent managed stands which will have to be managed more intensely to protect them.

The Forplan model used in the present generation of Forest Plans in this Region, on initial runs, selected heavily from the Spruce/fir type due to the higher values. Because other pests were having an impact in the pine type the runs were required to take high risk pine type. This shortcoming in the model still exists as pest impacts have not been incorporated into it. One can make a strong argument that the planning effort did not incorporate pest concerns adequately. However, the planning process was driven by issues and not management concerns. Had the planning process been more supply oriented, perhaps a different result been achieved. As an additional concern it must be kept in mind that the present models do not do a very good job of integrating the capabilities of soil and water to produce vegetation outputs and their resultant pest responses in a manner that develops viable resource management alternatives.

The decision to take action against a forest pest is based on the threat the pest presents to management objectives. If the pest will prevent the attainment of the management objectives then action is taken against it.

The public has a wide degree of knowledge on forest ecology. Depending upon the location and the makeup of the concerned public any response can be encountered. To often though the public is reluctant to accept change in the forest until an outbreak is well underway.

Adequate technology is available. Broader application and monitoring of that technology will result in the identification of needed improvements. As ecosystems change for whatever reason, so must the technology change. .

With SB, I believe that our application of pest management practices has reduced the amount of pest losses we would have experienced had not these practices been applied.

It has been our experience that the public has both helped and hindered decisions relating to forest health.

We have improved the publics understanding that pests are a part of the ecosystem and serve a role that is a two edged sword. Whether their role is acceptable or not depends upon the management objectives and the public expectations. In general we find greater acceptance to treat the problem(the forest) rather than the symptom(the pest).

The Spruce/fir type is primarily on NFS administered lands. No known relationships between land ownership and SB incidence have been observed.

Other insect pests considered significant in R-3 are

(1) apsen defoliators
(2) Ips bark beetles
(3) Engelmann spruce beetle.

James Linnane

Ecosystems and geographic "area covered" in this analysis:

Geographic area considered for "other forest pests" is forested lands in Arizona and New Mexico.

Ecosystems:

1. Aspen defoliators: Forest Cover Type-- Aspen (SAF-217)

2. Ips Bark Beetles: Forest Cover Type of Principal Concern-- Interior Ponderosa Pine (SAF-237)

3. Spruce Beetle: Forest Cover Type-- Engelmann Spruce-Subalpine Fir (SAF-206)

Very brief history and biology of each pest (or group of pests):

Aspen Defoliators: Western Tent Caterpillar, *Malacosoma californicum* (Packard), and Large Aspen Tortrix, *Choristoneura conflictana* (Walker).

Distribution: These insects principal host is aspen, *Populus tremuloides* Michx.. Aspen can be found throughout the Region (344,782 acres), generally at elevations above 8000 ft MSL. Insect populations can generally found throughout the distributional range of aspen. It is common to find populations of both defoliators in the same stands.

Life cycle--western tent caterpillar: One generation per year is the most common. Eggs are laid in bands on host twigs and small branches from mid-July to August. L-1 overwinters in the egg and emerges in the spring as foliage flushes. Early larval stages feed gregariously and construct silken tents. Mature larvae (4 to 6 weeks after spring emergence) disperse, seeking pupation sites. Pupal stage averages two weeks. Adults can be found from mid-July through August.

Life cycle--large aspen tortrix: One generation per year is the most common. Eggs are laid in masses on host leaves during July. Larvae emerge and seek overwintering sites on the host (August and September). Overwinters as second instar larvae. Larvae emerge in the late spring as aspen buds swell. Immature larvae mine buds and mature larvae web or tie leaves while feeding on foliage. Pupae are found in rolled-leaves during mid-June through mid-July. Adults emerge in July.

Cycles and Triggers: There is little data available on these topics. Cycles are variable in duration, likely in response to climate or weather patterns. Triggers may be related to the percentage of mature to overmature aspen

comprising stands. Subtle changes in host biochemistry combined with favorable weather patterns may result in conditions favoring the defoliators. Insect populations, under favorable conditions, generally expand for 1 to 3 years followed by a decline or abrupt collapse. Population collapse has been associated with widespread viral disease or adverse changes in weather.

Ips Bark Beetles: Principal species of concern are Ips lecontei Swaine (Arizona five-spinned ips), and I. pini (Say) (pine engraver).

Distribution: Ponderosa pine cover type in Arizona and New Mexico, 7.3MM acres.

Life Cycle: Ips are multivoltine with 2 to 5 generations annually. Generally overwinter as adults. Eggs are laid in galleries under the bark. Larvae are cambium feeders. Larval and pupal stages are found under the bark. Adults emerge, mate, and disperse to attack new hosts.

Cycles and Triggers: Outbreak populations are associated with drought conditions, management practices which create large or continuous amounts of green slash, wildfire damage, and blowdown. Generally, populations build in green slash or fresh down material. When slash is plentiful, large numbers of beetles are produced. The second or third generation in a given year may attack standing trees, particularly if green slash is unavailable. I. lecontei is the more aggressive species, associated with more attacks to standing trees. I. pini may be more common.

Spruce Beetle: Dendroctonus rufipennis (Kirby)

Distribution: Spruce-fir cover type in Arizona and New Mexico, 542,856 acres. Recent outbreaks have occurred on the Santa Fe and Apache-Sitgreaves National Forsests, and the Fort Apache Indian Reservation.

Life Cycle: D. rufipennis has predominantly a 2 year life cycle, although a 1 and 3 year cycle may occur. Adults attack host trees (Engelmann spruce) during May, June, and possibly early July. Egg gallery construction and oviposition continue through the summer. Immature larvae are present by October and overwinter. Larvae resume feeding in the spring and develop to pupae before late summer. Pupae transform to adults which overwinter a second time (2 year cycle). These adults emerge in the late spring.

Cycles and triggers: Spruce beetles generally prefer to colonize green windthrown or other downed spruce. Outbreaks may initiate after a major forest disturbance (ie, a large windthrow) creates an abundance of suitable breeding material. Populations rapdly increase in the down material and then readily attack standing spruce. Stands susceptible to attack are characterized by high basal area of spruce (>150 ft/ac), average spruce diameter above 16 inches dbh, species composition of greater 65% spruce, and on good sites.

Summarize the current status of the potentially most destructive pests (or group of pests) in the complex.

Aspen defoliators: Approximately 40,000 acres were defoliated Region-wide during 1986. Marssonina leaf spot disease was associated with this defoliation

in New Mexico. Early defoliation estimates for 1987 appear less (based on aerial survey). No other data is available.

Ips Bark Beetles: Approximately 2400 acres of ips damage was identified during aerial surveys in 1986. During 1985 and 1984, 7100 and 13150 acres of damage was detected aerially, respectively. Damage is principally mortality of poles and small sawtimber. During recent years, populations have been associated with timber management activities, ie, harvesting and TSI.

Spruce Beetle--Arizona: The most recent outbreak on the Ft. Apache Indian Reservation and portions of the Apache-Sitgreaves National Forest has largely subsided after 6 years of activity, 1981-86. It is very likely the outbreak commenced in the late 1960's and abruptly collapsed in 1971 as a result of unusally cold winter weather. Populations resurged, and during the last 6 years, over 100MM board ft of spruce has been killed. This estimate excludes a 7500 ac wilderness area on the Reservation which has been heavily infested. The outbreak has been concentrated on approximately 38M ac of Indian land and a few hundred acres in the Mt. Baldy Wilderness, Apache-Sitgreaves National Forests.

Spruce Beetle--New Mexico: The current outbreak on the Santa Fe National Forest began in the early 1980's and continues through 1987. Approximately 1200 acres were affected in 1986, almost entirely within the Pecos Wilderness. Other beetle activity occurred on the Santa Fe and Carson National Forests in the late 1970's.

Percent of host is occupied.

Aspen Defoliators: 1986--11.6%

Ips: 1986-->1%

Spruce Beetle: 1986-->1%

Acres occupied

Aspen Defoliators: 1986--40,000 ac

Ips: 1986--2400 ac

Spruce Beetle: 1986--1220 ac

Probable course of the infestation or infection

Aspen defoliators: Defoliation will likely follow historic trends, flucuating widely from year to year.

Ips: Populations can be expected to increase should drier conditions be encountered during the next few years. An increase in timber management activites will also increase to risk of damage by this pest.

Spruce Beetle--New Mexico: The remaining infestation on the Santa Fe National Forest will likely subside during the next few years. Other future outbreaks

are possible on the Santa Fe and Carson NF in remaining old growth stands. The acreage affected is likely to be smaller than recent outbreaks simply because most susceptible stands have already been devastated by spruce beetle. There is a high probability any future outbreaks will occur within wilderness areas.

What might cause or trigger an infestation or infection?

Aspen Defoliators: Cause or trigger (biologically) has been previously discussed. Increased defoliation by these pests may be a result of a greater percentage of stands being in a mature to overmature condition, fewer young stands, and generally less than ideal or historic age class distribution. Existing stands are largely the result of wildfire or other catastrophic disturbance. Modern fire suppression techniques have reduced wildfire acreage and, therefore, the acreage of potential aspen reproduction, thus reducing the acreage in younger age classes. The forest planning effort has recognized aspen as an important resource, but management (silviculturally) to regenerate existing stands has been greatly limited by lack of good markets. A large percentage of aspen in R-3 is within wilderness boundries thus precluding management.

Ips: As previously mentioned, a combination of dry weather or lower than normal precipatation and timber management activities where green slash is created can trigger an infestation. We have no control over the weather. However, management decisions to create slash during the late winter, spring, and early summer and to do so consistently in adjacent areas, year after year, can lead to serious infestation levels.

Spruce Beetle: Risk to spruce beetle attack exists in highly susceptible stands as previously described. Triggers are likely natural catastrophes, i.e., extensive blowdown in or around susceptible stands. Management activities, whether to salvage beetle killed wood or to regenerate stands, can aggravate the problem. Current silvicultural practices of and clearcut regeneration do not offer a great deal of hope in lessening spruce beetle risks in old growth stands. Fear of windthrow and high costs of harvesting operations have largely lead to decisions emphasizing clearcut regeneration methods. Where clearcut harvests are undertaken, extra precautions to remove or treat cull material, and monitor and remove or treat subsequent blowdown must be implemented.

Describe the possible responses

Aspen Defoliators: Insect populations, potentially, can be managed using direct suppression with insecticides. No treatments of this type have been attempted.

Ips The best response to a threat of ips infestation is a preventive strategy. This approach minimizes the amount of green slash or logging debris created during the late winter, spring, and early summer particularly when below normal precipitation conditons exist. Where management actions are necessary, they are spaced by distance and time (ie alternate years). Other responses include various slash treatment methods such as chipping, burning, and covering with plastic. Treatment of slash with insecticides is also possible.

Other than recommendations for use of the preventive strategy, no treatments of ips have been accomplished since 1983.

Spruce Beetle: Salvage or presalvage logging.

Describe the expected accumulative impacts associated with this complex of infestations or infections

General impacts

Aspen Defoliators: Several consecutive years of defoliation result in measureable radial growth loss, top-kill, and branch dieback. Tree mortality is possible in severe outbreaks. Defoliation accelerates stand decline by increasing susceptibility to pathogens. Accelerates forest succession to conifers. Resource impacts are largely a degradation of visual quality. Since timber markets are scarce, losses are neglible. Little information exists on impacts to wildlife.

Ips: Infestations are generally localized, not affecting large acreages. Mortality is usually limited to poles and small sawtimber, but can result in a substantial reduction in stocking levels within a given infestation. In managed stands, tree mortality associated with ips infestations can result in stands being understocked for decades. This is particularly important where TSI dollars have been invested to improve growth and yield.

Spruce Beetle: Spruce beetle outbreaks result in tree mortality principally in sawtimber size classes. In some stands, basal area can be reduced by 50-60%.

Specific impacts

Aspen Defoliators: No specific data exists.

Ips: No specific data exists.

Spruce Beetle: Ft. Apache Indian Reservation had the following losses:

1. 100MM + BF loss in spruce.
2. Reductions of 18 to 40% spruce basal area.
3. Tree per acre losses of 16 to 25 spruce.

Control Response(s)

Aspen Defoliators: High value stands could treated with insecticides.

Ips: See strategies mentioned under "Possible responses".

Spruce Beetle: Response limited to presalvage or salvage logging. Generally a "mop-up" action where some of the loss can be recouped.

What would happen if no action is taken?

Aspen Defoliators: See general impacts.

Ips: See "general impacts."

Spruce Beetle: See "general and specific impacts."

What could be done to prevent future infestations or infections?

Aspen Defoliators: Silvicultural approaches may reduce numbers of susceptible stands. However, many key visual quality areas are within wilderness boundries, precluding this approach. No information on the success of this strategy is available.

Ips: Preventive strategies are well developed and should be implemented when high risk situations occur. Monitoring conditions and populations is necessary to determine when strategies need be implemented.

Spruce Beetle: The strategy would be to identify and schedule for silvicultural treatment, high risk stands. Shelterwood regeneration methods or intermediate cuts (thinning) may allow greater acreages to be treated with a given volume of cut. Particular attention would have to be given to cull material, tops, and stump heights.

Technology Information

Aspen Defoliators: Generally, little information is available on this subject. Additional research efforts on relationships between pest outbreaks and stand conditions is needed.

Ips: Existing technology appears adequate to reduce losses during infestations. Additional information on monitoring populations could be helpful.

Spruce Beetle: Research on the effects of various silvicultural strategies on spruce beetle risk need be done.

Treatment Options

Describe treatment techniques, accomplishments and costs

Aspen Defoliators: Direct suppression with aerial applications of insecticides. Estimated cost $8-10/acre.

Ips: Preventive strategies--costs are indirect related to adjusting scheduled actions and contract clauses. Monitoring costs are part of normal survey and technical assistance expenditures.

Direct treatments--$100 to $300 per acre

Spruce Beetle: Salvage or presalvage logging generally generates dollars to pay for such operations. However, these approaches have little effect on the outbreak progession.

Prevention strategies generally will generate dollars, since material removed is usually merchantable.

Discuss the observed and expected trends of the next decade for these pests.

Aspen Defoliators: No specific data is available to predict the trend of these pests over the next decade. We do not expect substanial differences from the situation during the last decade. Defoliation during this time period ranged from a few thousand acres to 40,000 + acres.

Ips: No specific data exists to predict probable trends. Should drier than normal conditions be encountered during the next decade, we can expect increased losses to ips.

Spruce Beetle: Large outbreaks are not probable during the next decade.

In addition to the information identified required elsewhere in the outline discuss the following:

1. The obstacles, if any, to the use of existing technology for preventing outbreaks of the pest.

Aspen defoliators: No attempts to prevent outbreaks have been made. The technology to do so may need development.

Ips: The only obstacle could be technology transfer to ranger district level staff.

Spruce Beetle: Silvicultural management of the spruce-fir cover type is not a high priority item, largely due to a lack of good markets or demand for spruce products. A substanial portion spruce-fir falls within wilderness boundries, precluding any management. Other factors include reluctance by managers to take risks in silvicultural treatments in spruce-fir, and lack of recognition of the spruce beetle threat to mature spruce.

2. The limitations placed on effective response to the pest by laws, policies of the Forest Service, and policies of other government (federal, state, local) agencies.

Aspen Defoliators: Since response to outbreaks has been non-existent, limitations have not been a problem. The large aspen acreage within wilderness boundries may limit response to future outbreaks should the need arise.

Ips: None identified

Spruce Beetle: The wilderness issue

3. Perceived questions:

a. To what extent is aging of the nation's forests related to the incidence of forest pest outbreaks?

Aspen Defoliators: The maturing of a substanial percentage of aspen stands may be adding to the problem. Specific data to support this trend is unavailable.

Ips: Unlikely forest aging has any correlation with ips problems.

Spruce Beetle: Since all infestations occur in mature to overmature stands, aging substantially increases the risk of infestation.

b. To what extent do forest plans and the NFS planning process address forest pests and forest health?

Aspen Defoliators: These pests have only a cursory mention in Forest Plans. No specific analysis relating to the aspen resource was attempted.

Ips: Ditto aspen defoliators

Spruce Beetle: Same as above

c. **What triggers a decision to take action against a forest pest?**

Aspen Defoliators: Generally, unacceptable damage levels may trigger concerns about the resource. This usually happens only after several years of observed defoliation. FPM has been reluctent to recommend treatment nor has funds generally been available to conduct treatments. Public concerns over the appearance of forest stands has a great influence on Forests "looking" at the problem.

Ips: The recognition of an existing or potential problem results in a request for evaluation and subsequent actions.

Spruce Beetle: Unacceptable and highly recognizable damage, however, no effective response exists for outbreak levels of beetles.

d. How does the public's knowledge of forest ecology and forest management influence decisions affecting forest health?

Aspen Defoliators: Generally, the lack of knowledge (in-depth information of forest ecosystems) may adversely effect efforts to management aspen.

Ips: Likely no effect.

Spruce Beetle: Lack of knowledge may adversely effect efforts to manage spruce-fir cover types to lessen pest losses.

e. **To what extent does the technology exist for enhancing and maintaining forest health?**

Aspen Defoliators: Silvicultural techniques for managing aspen are well developed. This is best approach for long range improvement of stand health where applicable.

Ips: Preventive strategies are well developed and easliy implemented.

Spruce Beetle: Silvicultural information on spruce-fir management exists and is well documented in Station publications.

f. **How have man-caused changes in natural dynamics of the forest ecosystem influencing fire activity, ecosystem diversity, and nutrient cycling affected the incidence of pest outbreaks?**

Aspen Defoliators: Fire suppression activities probably have had an effect in increasing the incidence of outbreaks. Again, no specific information to support this assumption is available.

Ips: Management actions (ie timber harvesting, TSI, prescribed fire) have increased the incidence of outbreaks.

Spruce Beetle: Largely unknown, timber management activities may have adversely influenced the incidence of outbreaks.

g. **How has the increased public involvement in the forest management decision-making process affected forest health?**

Aspen Defoliators: Likely, little impact directly. Timber management has likely been adversely impacted by public involvement (below cost sales etc.). This may indirectly effect forest health.

Ips: Likely no impact.

Spruce Beetle: Increased public involvement has likely limited the F.S. ability to manage spruce-fir, wilderness issues, cable logging, road construction, below cost sales, etc. are the issues.

h. **How have public perceptions about pest-caused damages, losses, value of losses, cost of treatment or prevention, and risks of treatment affected forest health?**

Aspen Defoliators: Generally, the public would like to see all healthly trees. However, where pest damages become obvious, certain publics would like to see action taken. Other publics are emotionally concerned about the use of pesticides and thus oppose such actions. Except for special interest groups (lumber industry), most publics do not support large scale timber management in aspen. These perceptions may adversely effect forest health.

Ips: Likely no impact

Spruce Beetle: Little information is available on this topic. We will have to wait until an outbreak gets going in a major ski area.

i. **How has forest landownership class affected forest health? Do the frequency and intensity of outbreaks by this pest vary by land ownership? What factors explain this difference?**

Aspen Defoliators: No known relationships.

Ips: No known relationships.

Spruce Beetle: No known relationships.
*

ATMOSPHERIC DEPOSITION IN NORTHERN FORESTS

M. Weiss

I. Types of deposition included in this report: This report emphasizes regional-scale air pollutants occurring over large forest regions. Regional air pollutants of greatest documented or potential effect on forests include oxidants (ozone is most important), trace metals (heavy metals are most important), and acid deposition (wet deposition of sulfuric and nitric acids and dry deposition of sulfate, nitrate and nitric acid are most important) (1). This report gives only limited attention to local pollutants such as sulfur dioxide or to global concerns such as climatic warming. General conclusions about the relative importance of regional vs. local pollutants and relative importance of acid deposition vs. photochemical oxidants and trace metals have been developed by the SAF (7). The potential gradual and subtle changes in the forest ecosystems associated with regional pollutants are viewed as more important than the localized changes near point sources (7). Based on existing evidence, photochemical oxidants and trace metals are seen as more important regional pollutants than acid deposition (7).

II. Ecosystems and geographic area covered in this report: This report considers the 20-State Northeastern Area/Region 9. Three major forest ecosystems occur within this area: Northern Forest dominated by the maple-birch-beech, white-red-jack pine and spruce-fir types; Central Forest which is dominated by the oak-hickory type; and Southern Forest which in NA includes the oak-pine and loblolly-shortleaf pine types(4). A fourth local ecosystem, montane boreal, occurs in the higher mountains of the Northeast and is dominated by the spruce-fir type. The report will be limited to review of the known or potential effects of regional air pollutants in natural forest stands. Problems specific to forest plantations, urban trees, or roadside tree are not included. Effects on plant species other than trees will also not be included.

III. Background:

1. Distribution of forest types in NA[a]

	Forest Type	Commercial timberland[a]	Productive reserved and other forest land[a]
		[Thousand acres]	
	White-red-jack pine	11,455	604
	Spruce-fir	17,553	3,641
	Loblolly-shortleaf pine	3,423	129
	Oak-pine	4,170	229
	Oak-hickory	49,956	2,146
	Oak-gum-cypress	623	5
	Elm-ash-cottonwood	19,074	997
	Maple-beech-birch	35,821	2,459
	Aspen-birch	19,243	1,188
	Non-stocked	4,823	124
Total		166,141	11,522

Source of above data: (2)

[a] Includes KY, ND, SD, KS AND NE In addition to 20 NA states

2. Vegetation affected: Woodman and Cowling (3) recently examined the strength of the current evidence for regional air pollution effects on forests using an adaptation of Koch's postulates[b] as a standard of diagnostic proof. They examined each of the major situations in which regional air pollution has been suspected as a cause of observed forest change. The results are summarized as follows:

Situation[c]	Degree of proof
Eastern white pine/foliar injury and reduced growth/ozone and other oxidants	Stands up to rigorous proof of cause (All of Koch's postulates satisfied)
High elevation spruce-fir/ mortality and reduced growth/ several pollutants	Circumstantial evidence of cause (None of Koch's postulates satisfied)
Sugar maple/mortality/several pollutants	Limited evidence of cause (None of Koch's postulates satisfied)
Low elevation coniferous forests (red spruce in New England and New York)/reduced growth and increased mortality/several pollutants	Limited evidence of cause (None of Koch's postulates satisfied)

[b] Koch's postulates or rules of proof of causality as adapted for abiotic diseases (such as those caused by air pollutants) and described by Woodman and Cowling (3) are as follows: "Rule 1-The injury or dysfunction symptoms observed in the case of individual trees in the forest must be associated consistently with the presence of the suspected causal factors. Rule 3-The same injury or dysfunction symptoms must be seen when healthy trees are exposed to the suspected causal factors under controlled conditions. Rule 3-Natural variation in resistance and susceptibility observed in forest trees also must be seen when clones of the same trees are exposed to the suspected causal factores under controlled conditions." All three rules must be met to prove a cause-effect relationship. Koch's postulates have been a standard in research on plant and animal diseases for many years.

[c] For detailed discussions of each of these situations, see report prepared by NA for the Forest Health Project section on other pests and forest declines.

Thus, using Koch's postulates as the standard of diagnostic proof, based on current evidence, injury from regional air pollution has been proven to occur on eastern white pine; Koch's postulates have not been satisfied for any of the other species-pollutant combinations considered (3). Other recent reviews of the evidence support the same conclusions (5,6,7,9,12). In summary, these reviews of the current evidence reveal the high degree of uncertainty that exists about the possible relationship of regional air pollutants to observed tree problems in Northern forests and why it is premature to reach definite conclusions about present or potential impacts.

3. Percent of area occupied by susceptible vegetation: This is a very difficult question that cannot yet be answered except in the general way used by Smith(1,4,16) and summarized below. The susceptibility of forest ecosystems to regional pollutants is poorly understood, although some information is available which suggests potential effects such as growth suppression without visible injury to foliage, harm to soils and other effects. Susceptibility to foliar injury by oxidants is known for some species, but foliar injury is only one of many possible effects.

The relative susceptiblity of several forest tree species to ozone and other oxidants has been determined through controlled exposure trials. Susceptibility to ozone has been judged by the degree of foliar injury. Of the various tree species susceptible to ozone, the most widely studied has been eastern white pine. Several excellent summaries are available on effects of ozone on white pine (10,13). Although some individuals are especially sensitive and may suffer foliar injury, the white pine resource as a whole is not immediately threatened. Historical reports (based in some cases on questionable symptomatology) show that when injury is reported in the forest that the injured trees are randomly scattered in the forest and are greatly outnumbered by the unaffected individuals. Such reports have been common since early in this century (3,10).

Susceptibility of trees to other regional pollutants has not been well studied and will not be easily determined. The mechanisms of injury are likely to be much more complex and symptoms are likely to be much less specific than those involved in foliar injury from ozone. Effects of the regional pollutants including ozone on various plant processes including reproduction are being studied in NAPAP.

Smith(4) has examined the evidence for potential effects of air pollutants on the forest ecosystems. For each ecosystem, he first identified the pollutants of primary concern. He then identified the potentially important interactions between the pollutants and the ecosystem. A summary follows:

Ecosystem	Pollutants of primary concern	Interactions[d]
Northern Forest	Acid precipitation; heavy metals; Also, photochemical oxidants in some coniferous areas	Class I and II
Central Forest	Acid precipitation; heavy metals; Also, photochemical oxidants in an area east of the Appalachians and north of Virginia.	Class I and II
Southern Forest	While exposed to the same pollutants as the other ecosystems, the pollutant amounts are generally less and judged to be of less potential importance.	Class I and II

[d] Smith (4) separated the many interactions of air pollutants and ecosystems into three broad classes. Class I interactions: Air pollution levels are low/forest ecosystem is acting as both a source and sink for pollutants/no or minimum adverse impact. Class II interactions: Air pollution levels are intermediate/subtle, adverse effects may occur in individual species or trees due to changed nutrient availabilty, changed metabolism, increased insect or pathogen activity and direct foliar injury /potential impacts on the ecosystem include altered composition, reduced growth and increased or decreased insect or disease damage. Class III interactions: Air pollution levels are high/individual trees may be severely injured or killed/ecosystem impacts can be severe and long term including major change in composition, and soil erosion. Class III interactions involve localized effects near point sources from pollutants such as sulfur dioxide. Smith considered Class II interactions to be most important because of their potential to lead to major changes in forest ecosystems, their subtle nature and their widespread occurrence. He considered Class III interactions to be relatively unimportant because they occur only in very localized areas.

Other workers have also examined the potential long-term subtle effects of regional pollution on forests (19) expressing the same or more serious concerns than identified by Smith.

IV. Current situation:

1. Symptoms: No visual symptoms have been identified as specifically associated with any of the regional pollutants except ozone. The foliar symptoms of ozone injury to trees and other plants have been discussed in numerous publications. There are numerous publications that discuss the symptomology of white pine, alone(10). The foliar symptoms on white pine have been the subject of much debate over the years and the debate is continuing.

In recent years, there has been much concern that regional air pollutants may have contributed to the general "symptoms" of growth loss, crown dieback and mortality observed in red spruce and balsam fir in mountainous areas of the Northeast as well as in some of the hardwood types. To date, there is no sound

evidence that would support such a conclusion. See above conclusions by Woodman and Cowling (3). There is a long history of damage from natural agents in the same areas. Determining what, if any, portion of the observed "symptoms" may be caused by air pollution will be extremely difficult. For further information, see the report on red spruce and balsam fir decline prepared by NA for the Forest Health Project section on other pests and forest declines.

2. Percent of affected vegetation exhibiting effects: None of the observed decline symptoms have been proven to be associated with regional air pollution. (See discussion on symptoms, above, and the reports on spruce-fir and hardwood declines prepared by NA for the Forest Health Project section on other pests and forest declines.) No regional surveys have recently been done for foliar symptoms of ozone injury to eastern white pine. The value of such a survey would be doubtful because of uncertainties about symptomatology.

3. Acres and ownership involved: See above for acres by type. All types and ecosystems are potentially at risk to some degree (see III, 3).

4.Course of the problem: Unknown. Foliar injury to eastern white pine, some apparently caused by ozone, has been reported periodically across the Northeast since at least 1908 (10). Records are not adequate to indicate a trend.

Unexplained mortality has occurred in the spruce-fir type, most recently beginning in the early 1960's (14). Data are not sufficient to indicate a trend in mortality. Not enough is known about the causes to make predictions. Air pollution has not been shown to be the cause (See III, 2)

5. Apparent cause of the problem: Injury to white pine foliage may be caused by several agents including ozone and various needle cast fungi (10). Various decline diseases have occurred in the the northern forest ecosystems. Many natural factors are associated with the decline diseases. For further information on the decline diseases, please see the report prepared by NA for the Forest Health Project section on other pests and decline diseases. The role of air pollution in the declines, if any, has yet to be scientifically established. (See III, 2)

V. Impacts: No impacts have been documented in the Northern forest ecosystems that have as yet been shown to be caused by regional-level pollutants. Foliar injury to eastern white pine, possibly caused by ozone, has not resulted in any documented widespread growth loss or mortality. The only documented case of widespread, unexplained mortality or growth loss in the Northern forest ecosystems is in red spruce and balsam fir stands in New England, New York and West Virginia. The mortality has occurred at all elevations, but has been more prevalent in the higher elevation than in the lower elevation stands (18). The decline in growth rate of red spruce is unrelated to elevation and has occurred from sea level to high elevation stands (17). Data are insufficient to determine whether there is a relationship between growth decline and elevation in balsam fir (17). Many of the higher elevation stands are reserved for uses other than timber production, and thus loss of the trees has little economic impact. Nevertheless, unexplained changes at higher elevations are a concern because of non-timber values and because of a possible relationship with some of the regional pollutants that are deposited in greater amounts at the higher elevations. Mortality and growth loss are an economic concern at lower elevations. Many natural factors are involved in the mortality including spruce beetle, eastern dwarf mistletoe and wind (5). The reduction in growth

rates may be associated with the natural maturation of these forests (17) as well as other natural factors (5). For further information on the causes of spruce-fir decline, please see the report prepared by NA for the Forest Health Project section on other pests and decline diseases. Although growth rates of overstory red spruce and balsam fir in New England have been decreasing, growth rates have been increasing in other softwood species (including white pine) and hardwood species (including sugar maple) studied in this area (8). Regional air pollution may cause effects that are not obvious. For example, overall suppression of growth rates from low-level ozone exposure is a possibility in the absence of visible effects based on some experiments (10,11,13,15). Other potential subtle effects are discussed by Smith (4,16), and summarized in III, above. Gradual, subtle effects on the forest ecosystems are viewed as a likely consequence of regional-level air pollution (4,7).

VI. Response options: Prudence suggests that continued efforts be made to reduce the emissions that lead to regional-level pollution. Remedial action may not be possible for some potential long term effects, for example to soil chemistry or the genetic base. The other option is to wait until the evidence for subtle effects has been documented, and hope that remedial action is still possible. In any case, the need for long term research is critical. For similar or other views see (3,4,7,19). Some workers suggest that based on current evidence strong action be taken now to reduce emissions (19).

VII. Treatment options: No proven, practical methods are available to prevent or ameliorate effects of regional level pollutants to vegetation or other components of the ecosystems. Planting of resistant strains(13), or soil treatments(7,16) have been discussed. Until the cause-effect relationships are understood, treatments should probably not be recommended.

VIII. Additional information:
1. The most significant limitation to an effective response is "on again-off again" funding for air pollution effects research that has been the pattern of the past several decades. Research aimed at understanding ecosystem effects beyond immediate foliar injury from gaseous pollutants must be long-term. The end of the NAPAP program will leave us with incomplete answers to the questions of long term subtle effects from exposure of these ecosystems to low or high levels of regional pollutants. Because of public pressure, much of NAPAP research is concerned with acid deposition. This direction may prove to be wrong in the long run given expert opinion that some of the other regional pollutants may be more important hazards. Fortunately, some research is being done on the other regional pollutants during the NAPAP program. Whether it is adequate will need to be evaluated at the end of NAPAP.

2. Perceived questions:
a. See separate reports prepared by NA on other pests and forest decline diseases for discussion of the relationship of aging to forest decline diseases and outbreaks of defoliators. Aging is accompanied by many natural changes that make the recognition of any separate, subtle effects of air pollution effects difficult.

b. The Regional Standards and Guidelines applicable to all National Forest land in the Eastern Region call for identification of present and potential impairment of National Forest resources attributable to air pollution, and for Forests to seek to have emissions reduced as needed to protect National Forest resources. The public had opportunity to raise issues during the preparation of State Forest Resource plans. The summary of issues shows that "acid rain" was

raised as an issue in three of the 20 states-NH, NY, PN. The strongest issue statement was in NY where the Plan called for a team to "determine whether acid precipitation poses a threat to the forest ecosystem in NY State". Since these plans were completed by no later than 1983, they may not accurately reflect what appears to have been a increased awareness of air pollution and forest health since 1983.

c. Action will probably be triggered by widespread public indignation over a problem, real or perceived, that may affect current or future human enjoyment of the ecosystems or could directly affect human health.

d. Most of the public's knowledge is cursory and thus the public has little way to evaluate information received via news media or other sources. The tendency is to overreact, which can contribute to the short term emergency response rather than sustained programs needed to understand this complex problem.

e. See answer under VII, above.

f. Some studies have shown that trees injured by air pollutants can be pre-disposed to attack by insects and fungi (12,13,16). Studies of pre-disposition are lacking for the Northern ecosystems. The changes in the ecosystems of the Northern forest due to human activity (other than air pollution) have been dramatic and vastly compound the problem of understanding whether changes that occur are natural or attributable to past or recent human activity.

g. Public involvement has probably served to raise the awareness of forest managers of the need to consider forest health and air pollution in resource management and protection decisions.

h. not applicable

i. Differences between ownerships have not been documented. Differences are possible to the extent that management practices vary and in turn affect susceptibility to air pollution. For example, some landowners might plant species highly susceptible to ozone injury.

X. Recommendations:
1. Further analysis needed: Further analysis is needed of past and future trends in levels of regional pollutants by type of pollutant and ecosystem in order that research and management priorities can be properly placed. Historical summaries of past pollutant exposure of each ecosystem are needed in order to assess needs and priorities for research on any long term, cumulative effects. Further analysis is needed of the relative potential damage to the ecosystem by each pollutant or combination of pollutants. Some analyses of these kind are currently underway as part of NAPAP.

2. Added information needed: Further analysis will be hindered by the poor information on the relative hazard of the different pollutants, the synergistic or additive effects of multiple pollutants, the potential effects of pollutants upon several plant processes, the possible predisposition of trees to other agents when affected by pollutants, and possible delayed response of trees to pollution.

3. Actions needed now: As suggested earlier (See VI), prudence suggests that emissions be kept as low as possible at least until more information is

available. Better records need to be kept of changes in the forest in order that unusual changes might be connected in time and space with changes in pollutant levels or other events.

4. Actions needed within 5 years: As suggested previously in this report (See VIII, 1.), the major need is for sustained research. The possible long-term effects on health of the forest from exposure to regional pollutants cannot be adequately assessed at present because information on the effects of these pollutants is fragmentary.

5. Additional thoughts:

We should not assume that regional air pollution is not a serious problem because Koch's postulates are not satisfied in most present situations. As research continues and evidence accumulates, the importance of regional air pollution can be more clearly assessed.

Class II interactions (4,16) need to be more carefully considered. Subtle changes could be more important than the more dramatic mortality and other general "symptoms" of decline.

We could be putting too much effort into explaining what has already happened. Some of the noticeable problems of today e.g. red spruce mortality, are not easily explained at least in part because the factors involved may no longer be present and identifiable. These kinds of attention-drawing problems could take attention away from new changes in the forest or potentially important long term problems associated with pollutants.

Much more research is needed on the various decline diseases. The etiology of this group of diseases is poorly understood, specifically the role of natural agents (insects, pathogens and weather) and the degree to which air pollution might be involved. The lack of sound information on the decline diseases is a serious limitation to survey and interpretation of supposed acute or subtle effects of regional air pollutants on the ecosystems.

Another need is for improved surveys and better record keeping. Surveys need to be intensive enough to provide early detection of changes so that the changes in the forest might be compared in time and space with changes in pollution levels or other events. Current FPM detection surveys fail to meet this need since they are designed to locate cyclic outbreaks of major pests after the damage has reached a level detectable by aircraft or cursory ground survey and are usually limited to economically important timber areas. Surveys carried out by the Forest Inventory and Analysis Research staff also do not meet this need.

X. References: Given the voluminous literature on air pollution effects on forests we have relied primarily on summary documents as references rather than original source documents.

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ATMOSPHERIC DEPOSITION IN THE SOUTH

David B. Drummond

TYPES OF DEPOSITION

Work over the last 30 years has led the research community dealing with atmospheric deposition to concentrate on ozone, sulphur dioxide, fluoride, and recently, precipitation that is more acidic than expected.

Other pollutants, including particulates and those that originate from small local sources or spills will not be discussed since their long term effects on forest health will be minimal.

ECOSYSTEMS AND GEOGRAPHIC AREA

All ecosystems in the thirteen state Southern Region that support forests are considered. By the very nature of the problem the probability of exposure has less to do with ecosystem or species than it does with proximity to a source, and with those exceptions where physical location or topography define forest type and how pollutants are distributed. The Southern Region is made up of 3 physiographic regions: mountain, piedmont and Coastal Plain. The forest management types and the acres in each are (exclusive of KY):

Management Type	Acres (Millions) 1/
Pine plantations	21.6
Natural pine	40.5
Mixed pine-hardwood	26.8
Upland hardwood	62.5
Bottomland hardwood	30.1
Total	181.5

Although not broken down by management type, the amount of timberland in Kentucky reported by Forest Inventory and Analysis (FIA) in 1975 is 11.9 million acres (Kingsley & Powell, 1978). The total acreage of forest land for the Southern Region is 193.4 million acres.

BACKGROUND

Distribution

Historically air pollution in the Southern Region had been a point source phenomonen. Documentation of ozone caused symptoms on eastern white pine in the mountainous areas of Virginia and North Carolina in

1/ From: The South's Fourth Forest: Alternatives for the Future. Review Draft. Washington, DC: USDA Forest Service, 1987. 611p.

the '50s and '60s suggested that concern was warranted that pollution over large areas was possible. Early work on ozone was initiated by Dr. Charles Berry in western NC. His work paralleled that of Dr. Leon Dochinger, Delaware OH. These two Forest Service scientists did some of the early work on determining that ozone and sulfur dioxide could cause foliar damage to trees, eastern white pine in particular, adjacent to as well as remote from obvious sources. In addition they showed that along with the visually obvious damage to the foliage there was a significant growth reduction. This was noted for both ozone and SO2. Of particular significance was Dochinger's work that showed that chlorotic dwarf of eastern white pine was a synergistic response to the presence of both pollutants (Dochinger, et. al. 1970) .

Other research on ozone and several other pollutants began in agriculture and forestry in the eastern United States in the '60s and has continued to the present. Much of this work was done with ozone and sulfur dioxide and was aimed at forest tree species. Surveys by Forest Insect and Disease Management personnel during this time are summarized in a 1979 WO review by FIDM entitled "Air Pollution Effects On Forest Vegetation and the Role of Forest Insect and Disease Management". This review provided information for all Forest Service regions.

Changes in acidification began to be noticed by Oden toward the end of the '60s in Europe (Ottar, 1984). Although there have been significant changes in the pH of lakes and ground water in North America with accompanying adverse effects to aquatic life, no concrete evidence is yet available that acid rain is affecting growth of forests.

Accelerated decline in Europe, which Europeans feel began as a growth reduction, has caused alarm in the USA as a result of FIA data which suggest growth reductions have occurred in parts of the piedmont and mountain areas of the South over the last 10 year cycle when compared to previous cycles. There is much controversy and speculation concerning these apparent growth reductions.

Natural movement patterns of large air masses in the eastern United States have always contributed to a natural haze that could be found over the mountains during the summer months. This natural pattern exacerbates the problem in the eastern United States. Large air mass movement patterns allow the buildup of airborne contaminants from the industrial portions of the south, east and northeast, providing precursors for the formation of oxidant pollutants as well as the necessary materials to increase precipitation acidity over this region, and allowing them to circulate in such a way that long term exposure of eastern and southeastern forests to airborne toxicants is possible.

To confound the potential problem, when it was obvious that SO2 ground level concentrations were causing problems locally throughout the east, a move to reduce ground level concentrations was initiated by industry. This move was to increase smoke stack height (the height the pollutants were released). This reduced ground level concentrations of primary pollutants, but increased the amount of sulfur that remained in the atmosphere for extended time periods, allowing the conversion to sulfates to take place. These sulfates, plus the nitrates also released, are thought to be the primary culprits in increasing the acidity of precipitation. Because of the increase in this material in the atmosphere, the high elevation forests may be under more stress than lower elevation forests as these pollutants

are scrubbed from the atmosphere in condensate as air masses are forced upslope when they encounter mountains.

Vegetation affected

It is not known how all vegetation in the southern United States will respond to increased levels of air pollution, but over the last 20 years studies screening populations to determine their sensitivity, and observations under field conditions have given us some idea of the sensitivity of many forest plant species. The response of these species will vary individually, spacially, temporally and with changes in climate. In addition, not all species have been screened. There may be species important to southern forestry that have the potential to be severely affected by atmospheric deposition.

Species of importance to southern commercial forestry that are known to be sensitive to ozone are reported by Davis and Gerhold (1976):

White ash	White Oak
Green ash	Sycamore
Cottonwood	Tulip poplar
Loblolly pine	Walnut
Virginia Pine	

Several other species have been shown to be intermediate in sensitivity to ozone. The following species might show some effects if conditions are right and concentrations are sufficiently high:

Eastern white pine	Scarlet oak
Shortleaf pine	Black oak
Slash pine	Sweetgum

Species sensitive and intermediate in their response to SO2 and fluorides and are important to southern forestry include:

SO2		Fluorides	
sensitive	intermediate	sensitive	intermediate
Yellow birch	Red maple	Box elder	Red maple
Green ash	Cottonwood	E. white pine	Green ash
E. white pine	White oak	Loblolly pine	Basswood
	Basswood		

Plants commonly used to indicate the presence of pollutants include the following:

SO2	ozone	Fluoride
Sarsaparilla	White ash	New needles of most pines
Blackberry	Black cherry	Wild grape
Flowering dogwood	Blackberry	Gladiolus & several other monocots
Raspberry	Tulip poplar	
Bracken fern	Common milkweed	
	Native grape	
	Posion-ivy	
	E. white pine (cloned)	

Percent area covered by susceptible vegetation

This is unknown. On a southwide basis, data presented in the review draft The South's Fourth Forest (see footnote pg. 1) indicates that timbered land in the South covers 36% of the total land area. It is the predominant land use in the south. In Virginia, North Carolina, South Carolina, Georgia, Alabama, and Mississippi the area covered by timberland is greater than 50%.

Since we do not have a true feeling for the susceptibility of southern commercial species and what research is available suggests that some species, such as loblolly pine, are potentially sensitive, the possibility must be considered that all the timbered land in the South may be adversely affected by airborne toxicants.

CURRENT SITUATION

Symptoms Observed

Air pollutants, particularly those originating from a point source, usually will affect more than one species in an area. Symptoms are often similar in appearance on all deciduous species and on all coniferous species. Symptoms will also occur uniformly on the plant. There is some variation in response by species and because of this a good illustrative publication should be consulted prior to attempting diagnosis. The Forest Service has recently collaborated in the publication of such a document (Skelly, et. al., 1987).

Sulfur Dioxide

Conifers: As do many other pollutants, sulfur dioxide causes a tip necrosis. This damage often is more severe if the exposure occurs early in the growing season. The necrosis is generally reddish brown and can involve just the tip or all the needle except the tissue just next to the fascicle. Generally all needles on a tree will be damaged to the same extent. Banding of the needles can occur if exposed later in the season and the sensitive tissue is restricted. Because of the similarity of these symptoms to those caused by other pollutants, confirmation by checking other indicator plants is recommended.

Deciduous species: Ivory to brown interveinal necrosis is characteristic of sulfur dioxide damage to many deciduous species. The pattern of damage will depend on the venation of the leaf. Depending on the situation, damage may be uniform on the plant or will at least affect tissue that is similar in age.

Fluorides

Conifers: Because of the mobility of fluoride in plants, the symptoms usually are manifested as a chlorosis or necrosis toward the tips of the needles. Because of this the necrosis, or tip burn, may easily be confused with tip necrosis caused by other pollutants or causal agents.

Deciduous sp. As the fluoride moves in the plant tissue in deciduous species, it concentrates in the margins and tips of the leaves. As a result, necrosis and/or chlorosis will usually occur along the margins of the leaves.

Ozone

Ozone is the most widespread phytotoxic pollutant in the United States today. Because of the varying concentrations of ozone across the country, the responses will vary from chronic responses (responses to lower levels of the pollutant over a long period of time) to acute responses (those to high levels of a pollutant over shorter periods of time). Chronic responses are characterized by chlorosis, mottling, and in some cases growth reduction without a visible manifestation of exposure. Acute responses generally result in necrosis and chlorosis, with the necrosis taking on several patterns in the case of deciduous species.

Conifers: Acute exposures of conifers usually result in the development of tipburn on exposed, sensitive individuals. Some mottling may accompany the necrosis. Necrotic banding can also occur where a restricted zone in the middle of the needle will be killed. Subsequent to the banding, the tip of the needle will die, turning reddish brown and later fading to a light brown. In the case of pine, all needles in a fascicle will usually be affected equally.

Deciduous species: There are several visual manifestations of exposure to toxic levels of ozone exhibited by deciduous species. The most common of these is a stipple. The upper surface of leaves will show a tan, red, brown or purple to black coloration which may be generalized or appear as minute lesions. The symptoms may often be more intense on surfaces exposed to the sun. This can result in a pattern of damage on leaves that corresponds to those areas that were shaded by overlapping leaves during exposue.

Acid Rain

While reported growth reduction in the southeastern part of the United States (mentioned above) has given rise to speculation that acid rain may contribute to this growth reduction, no evidence has yet been presented to indicate that it is directly or indirectly responsible. No symptoms have been described in field situations that can be linked to acid rain.

In agriculture, no crop has yet been shown to suffer yield reductions as a result of exposure to acidic precipitation. Researchers working

with agriculture systems are postulating that if acid rain has an effect, it probably is in influencing the plants relationships with pathogens, other pollutants, insects, or other stresses. This is not to say that undiscovered effects are not present. The influence of acidic precipitation on how plants respond to other perturbations of their environment may very well be influenced by lower acidity of all types of precipitation. Research continues in this area.

<u>Percent of susceptible vegetation exhibiting effects</u>

Much of the vegetation in the south is susceptible to airborne pollutants when conditions are right (soil,climate, etc.) and the contaminants are present. Genetic variation in the susceptibility to pollutants also controls how much of a population will show symptoms. Eastern white pine for example generally has only 18 to 20% of the population that will visibly response to ozone. Virginia pine on the other hand will show more than 80% of the population sensitive to ozone, at least for the seed sources tested (Davis, 1972).

Certain species are consistent in their visible response to exposure, these are usually used as indicators that a pollutant is present in concentrations sufficient to cause adverse effects. Affected vegetation may not display visible evidence of exposure, thus true assessment of losses, except on a local scale where damage is visibly manifiested is not yet possible.

Research has suggested that significant losses in growth may be occurring (Phillips et. al., 1977). Past work has presented data that indicate that growth reduction (both height and diameter) is occurring at least where the studies were conducted, and that these reductions in growth are occurring without visible evidence (Phillips et. al., 1977; Treshow, 1967).

At present, while the potential for adverse effects may be great, the amount of vegetation actually visibly displaying symptoms in the south is quite limited. Probably much less that 0.01% and some of that injury would probably be interpreted as caused by something else. No data are available that give any insight to losses due to air pollution regardless of its visibility.

The above discussion is for the south as a whole. Damage near local sources will be much greater, and since the damage is visible in many of these cases some estimate can be made of losses at the local level. The damage in some of these cases can be extreme, but no estimates have been made of impact.

Acres and acres by ownership involved

Of the 193.4 million acres of timberland in Region 8, the acres by ownership and management type, excluding Kentucky's 11.9 million acres and approximately 65,000 acres of spruce-fir type, are as follows:[1/]

	Pine Plantations	Natural Pine	Mixed pine-hardwood	Hardwoods Upland	Hardwoods Bottomland	Total
	(thousands of acres)					
Nat. Forest	575	7,033	1,823	4,431	452	14,320
Other Public	562	1,945	953	1,915	1,823	7,198
For. Industry	13.652	8,679	5,672	6,832	7,162	42,087
Other private						
Farmer	1,812	8,170	5,472	17,677	6,678	39,809
Corporate	1,441	3,910	2,048	5,268	4,010	16.677
Individual	3,580	14,344	10,749	26,373	9,963	65,009

1/ From: The South's Fourth Forest: Alternatives for the Future. Review Draft. Washington, DC: USDA Forest Service, 1987. 611p.

Course of the problem

The course of the problem was outlined to some extent in the background section. The following briefly reiterates what has transpired. Symptoms expressed by plants exposed to SO_2 have been known to man for many years. Damage near sources of SO_2 have occurred in many situations in the past but have caused little concern until society expressed its displeasure with such damage. SO_2 damage in the eastern North American continent began in the mid to late 1800s and on into the early 1900s. Oxidant damage was first noted in the northeastern United States in the late 40's to early 50's. At about the same time, similar damage was noted in southern California. In the south, C. E. Barry, USDA Forest Service researcher was looking at symptoms on eastern white pine. The disease at that time was called white pine emergence tipburn. In 1963, Barry reported the possible relationship between emergence tipburn and ozone, and later documented that ozone was present at higher elevations at night (Barry, 1964). Point source pollution probably does not represent the real threat to southeastern forests. These are usually easily detected and monitored when there is a need or pressure to do so. The real threat is from wide area pollutants such as ozone and other contaminants that build in the atmosphere and are widely distributed.

As a result, ozone and other widely distributed pollutants will probably increase over the next several years before ways are found to mitigate the problem. Part of the difficulty is not fully understanding what is going on. If concentrations remain the same or increase, the following considerations may influence forest response in the South.

1. In agriculture, the more northern cultivars of several species seem to be less susceptible than do southern cultivars.
2. It is likely that eastern species will be affected more than western species because of the higher humidities that occur in the east.

3. Weather patterns in the east allow for many periods of stagnant air buildup to take place. Using isopleths of total numbers of forecast-days of high meteorological potential for air pollution in a five year period by Holzworth (Miller & McBride, 1975) and assuming that forest land acreage is evenly distributed across the southern states, the acres of forested land in each state in Region 8 that fell into the various potential classes were estimated (see table below). Almost half (82.8 million acres) fall into areas that have a high potential for air pollution buildup. This estimate is conservative since in most of the Appalacian states the areas with the most forested land is concentrated in areas that correspond to the areas of potential buildup.

	Number of Days of Potential Pollutant Buildup[1/] 1-10	10-20	20-30	30-40
	----(thousands of acres of timberland)-----			
Arkansas	10,527	4,147		
Alabama		863	13,162	7,552
Texas	1,091			
Louisiana	11,313	2,483		
Mississippi		9,965	6,107	
Georgia		11,061	4,942	
Florida		2,607		
South Carolina		6,552	4,610	364
Tennessee		3,881	3,622	5,433
Kentucky		3,808	3,332	4,760
North Carolina	4,589	4,773	6,425	2,386
Virginia	1,235	4,013	5,866	4,322
Kentucky		2,856	3,570	5,475
Total	28,755	57,009	51,636	30,292

What is the apparent cause of the problem?

The cause of visible damage and some growth reduction is undoubtedly due to ozone and sulfur dioxide. The work on chlorotic dwarf of white pine and white pine emergence tip burn are evidence enough to support this contention. There is not enough information available to speculate on the cause of the apparent reduction of growth in the south. No matter how much speculation occurs as to the cause, there is still no cause and effect evidence linking acid rain, ozone or any other pollutant to growth reductions over large geographic areas.

IMPACTS

Describe the impacts, to 1987, that are certain.

No impact has been documented over wide areas. Impacts that can be documented are the result of local sources, or areas where ozone concentrations have been monitored and visible foliar injury linked with such injury. However, an evaluation of the amount of actual loss, either in terms of volume or in terms of economics has not even been attempted with these problem areas.

The number of acres affected by these sources is not known. It might be possible to pull from the literature, a summary of affected areas, but this could not possibly include all such areas and would not provide a valid feel for the scope of the problem.

RESPONSE OPTIONS

What actions were or could be taken to minimize effects?

Increasing stack height at point sources of SO_2 was used as a solution in the 1960s to reduce ground-level concentrations. In those

1/ Derived: Miller & McBride, 1975 & The South's Fourth Forest (pg 6)

cases where this was used, recovery was noted in sensitive species close to the sources (Drummond & Wood, 1967). This was a solution that may have just moved the problem to another arena. Now that higher stacks have been built and used for at least 10 years, it is thought that the new stacks have increased the amount of sulfur and nitrogen that remains in the atmosphere, contributing to the precursors for increasing acidity of precipitation.

Little can be done to minimize effects on existing ecosystems unless some action is taken at the source of pollution to reduce emissions. Legislation both nationally and locally is in effect to accomplish this; however, in the case of auto exhaust, improvement due to reduction of emissions is counteracted by the increased use of the automobile.

Point sources are under both federal and state control, (in most states) and pressures are increasing for change in the effectiveness of enforcement or a strengthening of the laws in effect.

TREATMENT OPTIONS

Little is available to prevent, protect, or provide remedial treatment to plants exposed to air pollution. There are antioxidants that can be used on the short-term to protect plants grown in intensive systems such as agriculture, or in forest tree nurseries. One such compound also has antifungal properties (benomyl).

This is probably not a desirable approach unless seedlings are grown in an area of high pollution, and are to be outplanted to areas of low or minimal exposure to oxidant pollutants.

It has been recommended in the past to produce seedlings in the same area where they will be outplanted, particularly if they are to be planted in areas where they will be exposed to high concentrations of pollutants. In this way the sensitive members of the population are rouged by natural selection in the nursery and never make it to transplanting.

ADDITIONAL DISCUSSION ITEMS

1. Since controls must be accomplished by prevention, and aimed at the source, action will require the uniform application of laws at all government levels, and hopefully internationally.

The Forest Service needs a clearer definition of responsibility for atmospheric deposition related activities spelled out by the Clean Air Act. The forest can be both a source of and receptor of atmospheric contaminants and different FS staffs are involved from each aspect. Forest Pest Management should be involved in monitoring PSD (Prevention of Significant Deterioration) Class I and II areas. Region 8 has 9 Class I wilderness areas. Current surveys using indicator plants can identify the presence or absence of pollutants, but provide little insight as to the impact of these pollutants on the system. FPM will conduct these surveys, and if funded will do indepth evaluations.

2. Perceived questions

a. Pest outbreaks are exacerbated by abiotic and other biotic stress factors. As stand age increases, the individual is less able to

respond to changes in its environment, and as stresses of any kind increase the individual is less able to survive the adverse conditions.

b. Forest plans deal very little with atmospheric deposition in R-8 except as it might be involved in declines in general, and as it influences the use of fire as a management tool.

c. Action against atmospheric deposition is more the result of political pressure applied by the general public when a perceived harm is sufficiently great. Sometimes this action is forced before adequate data are available to aid in decision making.

d. The level of public knowledge of forest ecology and forest management has a great influence on forest health, particularly the lack of it. Many pressures on managers by the public are to increase rotation ages beyond pathological rotation and lead to many acres of timberland that are highly susceptible to insects and diseases. This is not restricted to the public. We have many forest managers that are without adequate training in the biological aspects of forestry and as a result, many decisions in management are economic or politically based and result in situations where the forest's health is compromised by management decisions based on short-term economic considerations. This may be particularly true in industry.

f. Movement toward monocultures will, if there is not sufficient genetic resistance in the population of the species planted, increase the possibility of significantly reducing growth over the life of a rotation.

g. Public involvement has, at least in one or two situations in the south, resulted in increasing rotations to ages that are way beyond those which can likely be maintained in a healthy condition.

h. Vocal publics in the South have interfered with the ability of resource managers to respond to forest pest problems with actions that have shown to be at least partially effective in reducing losses. In other situations they may force action prior to the acquisition of enough knowledge for even a rudimentary understanding of a pest or health problem. The response to the reduction of growth in the southeastern part of the US is an excellent example of such a situation.

i. Ownership patterns under most circumstances probably would not be a factor with regard to atmospheric deposition.

RECOMMENDATIONS

Further analysis needed

A complete review of existing data is needed. This is being done for several areas as part of the atmospheric deposition initatives. As these reviews continue they will probably point out areas where further analysis will be critical.

Added information needed

Better and more complete information is needed as to the true cause(s) of the apparent reduced growth reported for the piedmont and mountain areas of several states as well as some reduced growth in the area surveyed by the Southern Station's FIA unit.

Actions needed now

Public education: accurate and truthful, fully explaining both sides of controversy and what is truly known and unknown is needed. We need to try not to hide part of the picture. It would be to our disadvantage to do so.

Actions needed within 5 years

Strive for sound, well designed multidisciplinary studies, aimed at understanding the true causes for declines that are presently occurring, and determine to what extent atmospheric deposition is contributing to these declines. Good surveys, outlining the location and extent of large scale perturbations in the nation's forests are necessary. For the Forest Service to make an informed recommendation dealing with Clean Air Act responsibilities, the effects of potential pollutants must be known. To Date, no adequate system exists for either quantifying or qualifying the effects of pollutants on air quality values. Research is needed over the next 5 years that will demonstrate:

1. Acute and chronic effects of air pollutants (singly and in combination) on air quality related values.
2. Thresholds at which these values begin to be significantly impacted by air pollutants.
3. Length of time required for these ecosystems to recover from such pertibation.
4. Long-term effects of air pollutants on forest ecosystems..
5. Monitoring protocols for assessing short- and long-term impacts.

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ATMOSPHERIC DEPOSITION IN WESTERN FORESTS

Paul H. Dunn, Paul R. Miller,
Susan Barro, and Mark Fenn

Atmospheric deposition damage to western forests first attracted the attention of USDA Forest Service researchers in the 1960's. The work of a joint Forest Service and Environmental Protection Agency funded project established that damage to ponderosa and Jeffrey pine was attributed to ozone. What was originally thought to be a problem local to the Los Angeles basin is now known to occur in airsheds of the major cities along the West Coast. Current work on the FS/EPA Western Conifers Research Cooperative and studies by two Forest Service research work units is expanding atmospheric deposition research throughout the Western United States to define the nature and extent of the problem.

TYPES OF DEPOSITION

DRY DEPOSITION

Both dry and wet deposition significantly affects the forests in the Western United States. Dry deposition is continually removes pollutants from the atmosphere at ground level while wet deposition is less frequent, particularly in the West's summer dry climate (Marenco and Montan, 1976). Methods used to measure dry deposition are crude, but estimates indicate that dry deposition mechanisms account for more than 90 percent of the ambient load of acidic compounds deposited in the Los Angeles Basin (South Coast Air Quality Management District, 1984). Data from other areas in the West indicate that about 50 percent of the acidic compounds are deposited as dry deposition. Dry deposition refers to the accumulation or adsorption of gaseous and fine particulate pollutants on plant and soil surfaces. Compounds commonly contributing to dry deposition include oxidants, such as ozone, sulfur dioxide, sulfate, sulfuric acid, nitrogen dioxide, nitrate, nitric acid, ammonia, and ammonium. The expected biological effects of these compounds range from leaf tissue injury by sulfur dioxide (alone or in combination with ozone) to a nutrient or fertilizing effect from some of the nitrogen compounds. Deposition of nitrate and sulfate peak during the summer months (Bytnerowicz et al., 1987a).

The dry deposition of ozone is ubiquitous over regional airsheds, causes injury to sensitive species and is, therefore, the more important to study. Ozone is unique because it can accumulate in the lower atmosphere from two sources: brief stratospheric intrusions (Viezee et al., 1982) and photochemical synthesis from the precursors nitrogen dioxide and unsaturated hydrocarbons (Demerjian et al., 1974). Other oxidants--formic

acid, peroxyacetyl nitrate (PAN), peroxypropionyl nitrate (PPN), and hydrogen peroxide, are formed by photochemical reactions in the troposphere and, with the exception of PAN, have not been proved to be responsible for damage to forest vegetation at concentrations usually found in the ambient atmosphere. PAN damages some sensitive herbaceous species (Temple and Taylor, 1983), but not tree species (Kohut et al., 1976; Davis, 1977). It is important to acknowledge that these pollutants coexist with ozone because of the potential for joint action (Kohut et al., 1976; Temple and Taylor, 1983).

The nitric oxide-nitrogen dioxide conversion cycle, which is responsible for ozone production, has a predictable diurnal concentration pattern due to its dependence on solar radiation. In urban areas, nitric oxide reaches its daily peak at about 0800 hours, but is rapidly converted to nitrogen dioxide in a few hours. Relatively high concentrations of nitrogen dioxide may be present in the urban atmosphere during early morning and late evening hours. The ozone maximum in source areas generally occurs at about 1200 hours and is accompanied by rapid consumption of nitrogen dioxide. At downwind receptor areas, the transported parcels of "mature smog" would have lower concentrations of nitrogen dioxide (National Academy of Sciences, 1977). Formic acid, PAN, PPN, and hydrogen peroxide have the same diurnal concentration pattern as ozone with peak concentrations occurring at roughly the same time. Ozone levels return to background levels much faster than formic acid, PAN, or hydrogen peroxide at night (Tuazon et al., 1981).

The mechanisms by which nitrogen compounds in the form of dry deposition enter a plant vary. Nitric oxide is not readily absorbed either by leaf tissues (Hill, 1971) or by soil surfaces (Judeikis and Wren, 1978). Nitrogen dioxide is more water soluble and is readily absorbed by actively transpiring leaves. Alfalfa in the South Coast Air Basin may absorb as much as 0.28 kg/ha/day as nitrogen based on an assumed hourly concentration of 6.0 pphm nitrogen dioxide (Hill, 1971). Dry deposition of nitrogen dioxide to Scots pine (*Pinus sylvestris* L.) increased linearly as concentration increased in both laboratory and field experiments. In chaparral stands, the uptake of nitrogen dioxide may be limited mainly to the spring period when soil moisture is still available for active growth. Nitric acid may make up as much as 73 percent of the total nitrate in air in the San Gabriel Mountains of southern California. The usual range for each nitrogen compound was 69 to 86 percent NO_2, 9 to 15 percent NO_3, 4 to 11 percent nitric acid, 3 to 9 percent ammonium, and 1 to 2 percent NO (Bytnerowicz et al., 1987b).

WET DEPOSITION

In the West, wet deposition monitoring is much more advanced than dry deposition monitoring. All Western States are represented in the national network of wet deposition sites operated under the unifying guidance of the National Atmospheric Deposition Program (NADP). Acid fog, rime ice, and acid rain are the types of wet deposition being studied. Acid fogs with pH values ranging between 1.7 and 5.8 have been measured in the Los Angeles and San Joaquin Basins during periods of low inversion heights, weak transport winds, and weak offshore surface gradients (South Coast Air Quality Management District, 1984; Waldman et al., 1985). Fogs may last

several days and may be preceded or followed by episodes of high photochemical oxidant pollution. The occurrence of both ozone and fog episodes is enhanced by the marine climate, particularly the marine inversion layer. Rime ice is being tested in current studies and is more acid than snow from the same clouds. The ion content is many times the content in the snow. This difference would indicate some accumulation of acid ions in the ice formation process. Little acid rain occurs on the West Coast because of the procession of storms from the Pacific throughout the winter months. Certainly the winter rains are cleaner, with pH values ranging above 5 in most of California and the West. First monitoring results suggest that the greatest rainfall acidity (pH values between 3 and 5) occurs in light rains in the spring, summer, or early fall, convective storms draw acid-forming dry gases and particles up from nearby valleys.

A pulse of dry deposited nitrate and sulfate appears in the throughfall collectors when foliage is washed by the first rainfalls of the winter season; these amounts far exceed the accretion of nitrate and sulfate delivered by subsequent winter rains. The nitrate concentrations of several streams which drain from the San Gabriel Mountains of southern California exceed the Federal Standard for drinking water (10 ppm). In waters draining from areas more removed from the influence of urban, oxidant air pollution much lower concentrations are recorded (Riggan et al., 1985). Chemical delivery through snow pack may prove to be the dominant chemical input to alpine and subalpine ecosystems (Hicks et al., 1986).

SEASON AND DEPOSITION RATE

Seasonal conditions influence both environmental and biological variables that regulate vegetation responses to airborne chemicals or air pollutants. The physical environment before, during, and after pollutant exposure varies considerably with season, and the physiological state of plant tissue may range from active to dormant. Season also determines which pollutants tend to accumulate in the atmosphere. Ozone episodes are characteristic of the summer months when maximum sunlight is available to drive the ozone-forming reactions in the atmosphere. Episodes of high sulfur dioxide or hydrogen fluoride may occur in all seasons. Winter conditions favor sulfur dioxide episodes.

ECOSYSTEM EFFECTS OF ATMOSPHERIC DEPOSITION:

GEOGRAPHIC AREAS AT RISK

Atmospheric deposition studies in the West have been divided into two categories based on whether transport is long or short range. In studies of long-range transport, researchers are concerned with pollutants that have been mixed in the upper air layers and are transported on a regional scale with high-level air masses. The effects of long-range pollutants on alpine-subalpine vegetation and lakes far removed from the pollution source are examined in such studies. Although concentrations of these pollutants are generally low, they may affect the alpine-subalpine ecosystems after a long period of deposition. Some areas in the West have been identified as sensitive due to unbuffered soils and waters, but no harmful effects have yet been observed due to regional-scale transport of pollutants in the West.

The Forest Service and the Park Service have responsibility to protect air quality related values of wilderness lands under the Clean Air Act. Adverse impacts from atmospheric deposition are controlled through permits. Research attempts to identify the most sensitive parts of the wilderness for use in impact studies before permits are issued.

Short-range transported pollutants account for most of the observed damage to forests. Studies of short-range pollutant transport focus on areas downwind of the Los Angeles basin, the San Francisco/San Joaquin air basin, the areas downwind of the Pacific Northwest cities, and the cities in the valleys of the interior West, such as Missoula, Salt Lake City, Phoenix, Tucson, and Denver. Ozone concentrations are high and cause direct damage to sensitive vegetation as well as ecosystem-level disturbance in California. National Park Service investigators have found ozone injury to ponderosa pine in the Saguaro National Monument's Rincon Mountain area near Tucson. Of 670 trees surveyed in 1986, 19 percent showed ozone injury (personal communication, Kenneth Stolte, National Park Service, 1987). Ozone effects have not been clearly proven in the Northwest or near other interior cities, although vegetation surveys are being done.

SAROAD (Storage and Retrieval of Aerometric Data) files (U.S. Environmental Protection Agency, 1978, 1979, 1980, 1981, 1982) for ozone (Ludwig and Shelar, 1980) show the West, Northeast, and Gulf Coast regions have the greatest probability of exceeding the 0.12 ppm standard. Ozone data from eight relatively remote National Forest sites distributed throughout the United States were reported (Evans et al. 1983). The ozone concentrations during daylight hours were generally higher than 0.025 ppm during the April through October period but did not exceed an average of 0.054 ppm. In spite of the remote locations of these stations, several may have received ozone from urban areas. The Los Angeles urban plume has been traced as far as 350 km east to the Colorado River Valley, near Needles, California, where daily maximum ozone concentrations ranged from 0.07 to 0.08 ppm during an episode of high pollution. The long-term record at this location showed a range of 0.019 to 0.044 ppm for the daily peak (Hoffer et al., 1982).

Ozone symptoms on ponderosa and Jeffrey pines include the characteristic chlorotic mottle on the foliage of affected pines in addition to reduced needle length and reduced needle retention. Usually ozone symptoms appear first on the oldest needles and lowest branches. With increasing injury, symptoms progress to the younger needles and upper branches. Severely damaged trees will only retain the current year's needles on the twigs and will have dead crowns.

The most ozone injury to forest vegetation in the West continues to be observed in the San Bernardino and San Gabriel mountain ranges to the east of Los Angeles, where ponderosa, Jeffrey pines, white fir, and California black oak show various levels of foliage injury, defoliation, and growth loss. Actual mortality from ozone injury alone is not known. Trees die when drought stress and insect pests combine to destroy those weakened by ozone. On the western slopes of the Sierra Nevada, extending south from Sacramento to Bakersfield, forest surveys have identified ozone injury to sensitive pines as slight or occasionally moderate. Several locations in the Sequoia National Forest, particularly the Marble Fork drainage of the Kaweah River in Sequoia National Park, show pockets of moderate injury.

Nocturnal ozone concentrations are higher at mountain than at basin sites (Berry, 1964; Stasiuk and Coffey, 1974). In the coastal climate of California, the afternoon, inland flow of cleaner marine air undercuts the ozone-polluted air at the same time that the polluted air mass is being transported eastward (Edinger et al. 1972). Ozone remaining in the new marine layer is scavenged at night by fresh infusions of nitric oxide from basin sources, but ozone in layers aloft is partitioned from the continuing emissions of nitric oxide. The nighttime inversion in the Los Angeles Basin is typically about 600 m thick; above this, the stable air layers containing ozone may extend up to 3000 m (Farber et al. 1982) . Because of the generally lower pollution levels at these higher elevations, insufficient nitric oxide is available to scavenge (remove) ozone. Thus ozone levels at higher elevations remain elevated during the later afternoon and evening hours. We know of no studies to test the relative sensitivity of forest species in light and dark.

Even during daylight hours, the ozone concentration at Sky Forest in the San Bernardino Mountains (east of Los Angeles) is higher than the nearest basin station in the city of San Bernardino. The Sky Forest station is located at 1709 m elevation on a southfacing ridgecrest; it is 14.4 km north and 4.8 km east of the basin station (360 m elevation). The average hourly ozone concentrations for the daylight period (0600 to 2000 P.s.t) for all available hours were compared by the month for the 1968 to 1977 period (Table 1). The mountain concentration was higher in all 12 months. Correlation coefficients describing the relationships of paired daily average concentrations from the two stations were generally very low. This low correlation emphasizes that the air masses at each station were almost always decoupled.

Table 1. Daylight (0600 to 2000), monthly average ozone concentrations at two stations for each month from 1968 to 1977. Sky Forest is located 15 km NNE of San Bernardino.

Month	Average Concentration (ppm) San Bernardino (360 m)	Sky Forest (1709 m)	R^2
January	0.003	0.005	0.59
February	0.011	0.020	0.17
March	0.014	0.026	0.30
April	0.019	0.044	0.46
May	0.031	0.071	0.37
June	0.055	0.091	0.40
July	0.064	0.105	0.19
August	0.062	0.100	0.23
September	0.048	0.064	0.25
October	0.026	0.038	0.26
November	0.011	0.017	0.23
December	0.005	0.008	0.37
9 yr Grand Average	0.029	0.049	

In the southern portion of the Sierra Nevada, at locations influenced by oxidant polluted air transported upslope from the San Joaquin Valley, three monitoring stations were maintained from June through September from 1976 to 1981 (Vogler, 1982) (Table 2). These stations were located in the mixed conifer forest type where ozone damage symptoms to foliage of ponderosa pine and Jeffrey pine were considered to be mostly slight and occasionally moderate. The elevations of these stations were: Whitaker's Forest, 1654 m; Mountain Home, 1805 m; and Greenhorn Summit, 1860 m.

Table 2. Means of daytime hourly average ozone levels during the summer months at monitoring sites in the southern Sierra Nevada, 1976 to 1981.

	Mean daytime (0900-2000 P.s.t.) ozone value during June through September					
Site name	1976	1977	1978	1979	1980	1981
Whitaker's Forest	(.070)[a]	.084	.078	.079	.075	.082
Mountain Home	--	[.073]	.068	.071	.057	.073
Greenhorn Summit	--	--	.085	.084	(.082)	.086

Source: (Vogler, 1982).
[a] Of the years shown, 85 percent or more of the hours were recorded, except as follows: ( ) = 60 percent; [ ] = 45 percent.

Daily maximum hourly averages at the three mountain sites were often the same as the nearest urban sites in the San Joaquin Valley, and as observed in the San Bernardino Mountains, the nocturnal concentrations stayed in the range of 0.08 to 0.10 ppm. The daily maximum hourly average occurred between 1200 and 2000 hr P.s.t. at these stations and ranged from 0.10 to 0.16 ppm.

The valley of Mexico City has all the ingredients for a photochemical oxidant problem. The surrounding mountains and frequent temperature inversions during the cooler months allow accumulation of precursor chemicals from 3 million cars and other sources. Data from two ozone monitoring stations located in the northern and southern sections of the city have shown consistently higher concentrations and later peak times at the southern station. Winds are generally from the northeast. During the 1983-84 season the ozone concentration exceeded 0.12 ppm on 20 occasions (Bravo, 1987, personal communication). Pine and fir forests occupying the mountains 20 to 30 km southwest of Mexico City may be receiving severe damage from ozone and associated pollutants. In two National Parks in this region, investigations are underway to define the role of air pollution in the crown deterioration and eventual death of native tree species. In the Parque Nacional Cumbres De Ajusco, ozone was identified as the cause of foliar injury to Pinus hartwegii Lindl. and P. montezumae Lamb.,var. lindleyi by using several lines of circumstantial evidence, including the decrease of symptom severity as distance, southwest of the city increased, and after enclosure of branches in chambers equipped with activated carbon filters (Hernandez, 1984; de Lourdes de l.de Bauer et al., 1985). A short distance away in the Parque Nacional Desierto de Los Leones excess mortality has been noted in stands of Mexican sacred fir, (Abies religiosa (H. B. K.) Schl. et Cham.) in the mid to upper elevations and also in Hartwegii pine at elevations up to 3000 m. The symptoms of foliar injury on older needles and lower crown needles (Paul Miller, unpublished data), and the circumstantial evidence regarding urban ozone concentrations and direction of transport from the city strongly suggest that ozone is involved in this problem. Much of the forest affected in the Parque Nacional Desierto de Los Leones was clearcut in 1986. It is presently being replanted with more ozone resistant species and varieties.

In Canada, ozone monitoring networks are in place for specific regions only. Episodes of phytotoxic ozone concentrations occur principally in southern Ontario and the greater Vancouver area (Rennie, 1985). Some short-term measurements of ozone at both urban and remote sites in Alberta during spring and summer showed concentrations in the range of 0.011 to 0.046 ppm. Concurrent measurements of PAN showed peaks as high as 0.023 ppm (Peake et al., 1983).

Sulfur dioxide pollution is of considerable interest on a regional scale in the Southwest. For example, slightly elevated sulfate levels were detectable over wide areas when copper smelters were in full operation in Arizona (Oppenheimer et al. 1985). Single SO_2 sources located in forested areas where both topography and meteorology favor repeated fumigations have been reported (Scheffer and Hedgecock, 1955). Power generation plants, sour gas desulfurization plants, copper smelters, and oil shale development could present future problems where development is in

a forested area (e.g., if oil and gas exploration continues along the overthrust belt in the northern Rockies).

In the southern Sierra Nevada, east of Bakersfield, the possible effects of mixtures of ozone and sulfur dioxide on forest vegetation was monitored in an area downwind from oil refineries. The combined evidence from an analysis of soil and plant tissue for sulfur, air monitoring, and a survey of foliage symptoms clearly indicated that sulfur dioxide and ozone were not acting jointly to damage trees at these sites. All symptoms could be attributed to ozone.

TREE SPECIES AT RISK

Listings of the relative sensitivity of tree species to ozone have been compiled (Jacobson and Hill, 1970; Davis and Wilhour, 1976). Caution is recommended in the use of these sensitivity rankings because of the extreme variability of the methods used to assess ozone injury. The most common limitation is that only one or two plants of a given species were exposed to any single treatment (Genys and Heggestad, 1978). This condition prevents a representative estimate of population response, an important factor with forest species which have a large range of genetic variability. Work is currently underway in the NAPAP Western Conifers Research Cooperative to screen several western conifers for ozone and sulfur dioxide sensitivity with emphasis on treatments that simulate actual air quality data.

Many of the published sensitivity rankings are based on foliar injury, which is not necessarily the best indicator of performance following chronic stress. For example, nine deciduous tree species were exposed for 5 months to a low ozone dose and the differences in height growth were measured (Jensen, 1973). Ozone sensitivity of the same species were ranked on the basis of foliar symptoms (Davis and Wilhour, 1976). Their ranking was similar to that of Jensen for only three of the nine species. Height growth is probably the most meaningful estimate.

Seedlings of ponderosa, Jeffrey, digger pines, and giant sequoia were exposed to mixtures of ozone and sulfur dioxide in open top fumigation chambers (Taylor et al. 1986). Pollutant concentrations were similar to the ambient atmosphere near large industrial sources of sulfur dioxide and the worst case conditions of ozone exposure in the San Joaquin Valley. Both top and root growth of newly germinated seedlings was reduced more by mixtures of the two pollutants than by either alone, although root growth was more affected than top growth. These results suggest that the success of forest regeneration may be decreased if seedlings are exposed to these dose levels during the early establishment phase. Finally, the fumigation of older seedlings with pollutant mixtures resulted in modified needle symptoms, namely a shift from the light yellow chlorotic mottle caused by ozone alone, to a "brassy" colored mottle symptom.

A deterioration in the health and vigor of a single forest species due to a number of abiotic and biotic factors is referred to as "tree decline"; when more than one species is involved in a synchronous deterioration, the term "forest decline" is applied (Manion, 1981; Schutt and Cowling, 1985). Manion (1981) categorized factors involved in decline as predisposing

(climate, air pollutants, site, tree age, and genetic potential), inciting (frost, drought, and air pollutants), and contributing (bark beetles, root, and stem diseases caused by fungi). Air pollutants can be important as both predisposing (long-term) and inciting (short-term) factors. A review of the known examples of chronic injury by ozone to forest species in North America has been prepared by Smith (1984).

Chronic injury to foliage and reduction of leaf area may lead to reduction of stem growth. Chronic injury and growth reduction has been reported in the San Gabriel, San Bernardino, and Sierra Nevada mountain ranges of California. During the 10 years from 1974 to 1983, tree growth in the San Bernardino Mountains was measured in 18 vegetation plots along a gradient of high to low dose. Ponderosa pines with only one annual needle whorl retained in the live crown showed less than half the growth of pines with an average of three annual whorls retained. During these 10 years, ozone-sensitive tree species had less basal area increase than did the nonozone-sensitive trees. On plots located in the zone of high ozone concentration (0.08 to 0.12 ppm hourly average, May through September), 33.2 percent of ponderosa pine in the young mature age class (50-99 years) died. Only 6.9 percent of ponderosa pine trees in the same age class died on plots in the zone with lower (less than 0.08 ppm average) ozone concentration (McBride et al., 1985). The less severe injury and limited mortality was observed on the four other species in the same plots (*Abies concolor*, *P. lambertiana*, *Calocedrus decurrens* and *Quercus kelloggii*). This difference suggests that species composition undergos changes as a result of prolonged exposure to ozone. White fir, incense cedar, and sugar pine are all outgrowing ponderosa pine in areas where these species compete. A decrease in productivity of the most commercially important species (ponderosa pine), and increasing numbers of flammable species in the understory (incense and white fir), form a fuel ladder that could lead to devastating crown fires and destruction of the remaining overstory trees.

Southern Sierra Nevada conifer forests show injury levels that are mostly slight, and occasionally moderate, on the scale used to describe injury levels in the southern California mountains. For example, core samples collected from Jeffrey pines, with reduced needle retention (slight injury), at ozone exposed sites in Sequoia and Kings Canyon National Parks were compared with core samples from similar elevations, soils, and direction of slope in the upper Kern River Canyon where incursions of ozone were judged to be minimal (Peterson and Arbaugh, 1987). Ring width indices showed consistent and significant departures below predicted growth at the ozone exposed sites but only for large diameter, open-grown trees. Trees at the remote sites did not show this trend. Recent work in the Sequoia National Park area showed an 11 percent reduction compared to the expected growth curve but only for large diameter, open-grown Jeffrey pine on generally harsh sites. In a parallel study of ponderosa pines in the same areas, those trees with ozone symptoms showed no growth reduction (Peterson and Arbaugh, 1987). However, substantial growth reduction during the last 10 years at four ponderosa pine plots has been reported in the southern Sierras (Williams and Williams, 1986). More than 485,000 hectares of the ponderosa pine forests in the southern Sierra Nevada of California are estimated to be suffering effects of air pollution.

In summary, evidence from field studies and fumigation chamber studies provide clear evidence that ponderosa and Jeffrey pines are among the most sensitive of western conifers to ozone injury. The 26.6 million acres of commercial ponderosa pine timberlands throughout the West represent 25 percent of the total timberlands in the West (USDA, 1982). Ozone exposure risk varies by geographic area. Ozone levels are known to be high in southern and central California and in some areas of Colorado and Arizona. Detailed surveys of ozone exposure risk are now being conducted. There is some evidence that not all subspecies of ponderosa pine are equally sensitive to ozone. A survey of ponderosa ecotypes is also now underway.

CURRENT SITUATION:

The primary cause of the air pollution problem is clearly ozone. Ozone in combination with other environmental stress such as drought or disease or both lead to the most severe problems. The loss of needles reduces the photosynthetic capacity and the general health of the trees.

The concentration of ozone at 50 California and 15 Texas sites between 1973 and 1982 have been compared by using the average daily maximum (Walker, 1986). These sites represent both urban and nonurban situations. During the last 8 years, no decrease in ozone concentrations in California has been observed; in Texas, a slight increase (2.3 percent per year) has been found. Forest managers will have to manage trees in an ozone polluted atmosphere for the foreseeable future.

California forest managers have monitored the ponderosa and Jeffrey pine forest types for ozone damage. Symptoms of ozone damage on these pines were noted in the San Bernardino Mountains of southern California in the 1960's (Parmeter et al., 1962) and in the Sierra Nevada in 1970 (Miller and Millecan, 1971). The effects of ozone on conifers is best known in the San Bernardino Forest. Forest service management agencies have also monitored symptoms in the Sierra Nevada. The first work, begun in 1974, was to document where ozone injury symptoms, or chlorotic mottle, were present. In 1977, an intensive ground survey of 242 sites on the Sierra and Sequoia National Forest was completed. Since then, 54 of these plots have been revisited on a biennial basis (Pronos et al., 1978; Pronos and Vogler, 1981). One-time ground surveys of the Stanislaus (1981), Eldorado (1982), and Tahoe (1983) National Forest revealed that injury symptoms were present in all of these forests but were not as intense as those found on the Sierra and Sequoia National Forests. The chlorotic mottle of ozone damage is present over a 300-mile long area of the central and southern Sierra Nevada between elevations of 4000 and 8000 feet.

Visible symptoms of chlorotic mottle have increased in the eight years since the National Forest began monitoring plots in the southern and central Sierra Nevada (Table 3). The greatest increase in symptoms occurred between 1977 and 1980 after 2 years of serious moisture deficits throughout the survey area. Twelve trees had died on the trend plots since 1977; seven of these had severe ozone injury prior to death. Typically the dead trees were under 8 inches diameter at breast height and were suppressed with only a 2-year needle retention and symptoms on second year needles. Secondary insect activity was noted in some cases.

Table 3. Changes in ponderosa pine cholorotic mottle in plots in the southern and central Sierra Nevada.

Observations	1977	1984/85
Plots (total 54) with no symptoms	22	7
Plots with slight symptoms	23	24
Plots with moderate symptoms	9	16
Plots with severe symptoms	0	6
Plots with very severe symptoms	0	1

Source: J. Pronus, 1987.

Recent work by tree-ring analysis on Jeffrey pines with ozone symptoms shows an 11 percent reduction in d.b.h. corresponding with increased air pollution over the last 20 years. Ponderosa pines with ozone damage symptoms do not show the growth decline (Peterson and Arbaugh 1987). In the San Bernardino Mountains, the forests are further along in their decline. Many of the most sensitive ponderosa and Jeffrey pines are now dead and have been removed. Incense cedar is replacing them in the stands. Giant sequoia is also doing well in areas where it has been introduced. Since ponderosa and Jeffrey pines are not grown for timber in the San Bernardino Mountains, the growth loss is not as important as it is in the Sierra Nevada. However, other factors such as changing visual aspects, cost of removing dead trees, the cost of replanting with more ozone resistant seedlings, and the cost of cutting out incense cedar are important in both areas. Due to its branching pattern, and thus fuel loading, the presence of incense cedar will probably lead to an increase in crown fires due to the disruption of the ground fire forest type.

TREATMENT OPTIONS

The damage caused by ozone to forests in California range from slight to severe. Since ozone damage is relatively difficult to detect, the cumulative effects are made apparent by higher mortality rates due to primary pests during periods of drought stress. Mortality is also relatively low over a short term. In 8 years, the mortality of trees with ozone injury symptoms was 1 percent in the southern Sierra Nevada (Pronos, 1987). A casual observer or even a professional silviculturalist is not likely to conclude that these forests are suffering any unacceptable growth losses. In contrast, major insect and disease pests cause rapid and easily detectable damage that the forester routinely encounters and recognizes.

The only managerial tool now being tested to relieve this problem is the thinning of affected stands to remove excess stems in the understory and to remove weakened overstory trees. Three such plots are being monitored in the San Bernardino National Forest. In the Sierra Nevada, the gradual decline is being monitored by management. The most resistant of the surviving trees in southern California are being used as seed source for replanting.

RECOMMENDATIONS

Studies of atmospheric deposition effects on trees and forested ecosystems in the West are still in the research phase and have yielded few recommendations to management. More research needs to be done on screening trees and forested ecosystems for sensitivity before the true extent of the problem can be known. In California, ozone injury symptoms on conifer foliage serve to define the gradients of other dry-deposited pollutants. However, we do not know to what extent other dry-deposited pollutants may contribute to the leaf symptom (chlorotic mottle) which is caused by ozone. The best examples of ozone gradients are in the San Gabriel, San Bernardino, and San Jacinto mountains of southern California and the western slopes of the southern Sierra Nevada. The best opportunity for gradient studies is in the mountains of southern California, particularly because a background data base is available to provide useful guidance for a variety of new studies (Taylor, 1980). The particular advantage of the San Bernardino mountains is that the summer ozone dose is usually high enough to induce severe levels of injury in the sensitive individuals, thus providing a good contrast between maximum and minimum effects on physiological processes.

Three areas of the West should be given high priority for research. The first priority should be given to areas in California where the mixed conifer forest type is found. This type is comprised of ponderosa pine, Jeffrey pine, white fir, sugar pine, incense cedar, and black oak. These species now face the greatest risk from photochemical oxidants and associated wet and dry deposited acidic compounds in the West. Second priority should be the forest downwind of Tucson, Arizona where ozone damage has been reported to confirm the reports and gather more information on the extent of damage. Third priority should be wilderness areas where the effects of long range transport atmospheric deposition may be a problem. The need to issue permits to industries that produce atmospheric emissions which might affect the air quality of wilderness areas is a serious administrative problem. Other areas and vegetations should be given a lower priority due to low sensitivity of the dominant vegetation in previous screenings and lower atmospheric deposition problems.

New research should be balanced between the categories of "controlled environment" and "gradient studies." The planning process should result in an overlap of spatial scales (leaf, tree, and stand) in some studies where it is essential to test whether results from young trees in controlled conditions can be extrapolated to mature trees. The research should be designed to give answers on a forest ecosystem level and provide recommendations for management.

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☆U.S. Government Printing Office : 1988 -201-066/80244